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OUTLINES
OF
PHYSIOLOGY.

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OUTLINES
OF
PHYSIOLOGY.

WITH AN APPENDIX, CONTAINING HEADS OF LECTURES
ON PATHOLOGY AND THERAPEUTICS.

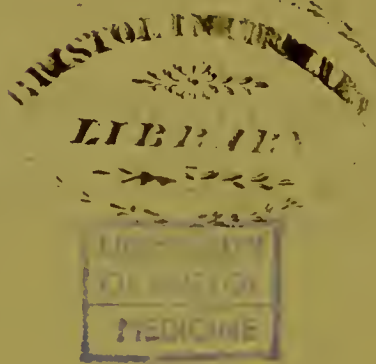
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OF EDINBURGH.

WILLIAM BLACKWOOD, EDINBURGH; AND
T. CADELL, STRAND, LONDON.

MDCCCXXXI.



NEILL & CO. PRINTERS,
Old Fish Market, Edinburgh.

TO

JOHN ABERCROMBIE, M. D.

FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS, AND

PRESIDENT OF THE MEDICO-CHIRURGICAL SOCIETY,

OF EDINBURGH ;

FIRST PHYSICIAN TO HIS MAJESTY FOR SCOTLAND ;

THIS VOLUME IS INSCRIBED,

IN TESTIMONY OF RESPECT

FOR HIS PROFESSIONAL AND SCIENTIFIC CHARACTER,

AND OF GRATITUDE FOR PERSONAL KINDNESS,

BY THE AUTHOR.

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PREFACE.

SOME apology may be thought necessary for the publication of a new elementary book upon Physiology, which contains no statements of new facts, within so short a time after the appearance of works of such value, on that subject, as the System of Dr BOSTOCK, the Outlines of Mr MAYO, and the Translations of BLUMENBACH'S Physiology, by Dr ELLIOTSON, and of MAGENDIE'S Physiology, by Dr MILLIGAN.

My apology is, that it appears to be important for a teacher of any branch of science to follow the arrangement which seems to his own mind the most satisfactory ; and important likewise for the students attending any course of scientific lectures, to have in their hands a text-book arranged on the same plan,

and containing the same views. The following pages have been written, therefore, for the sake of the medical students of this school. My objects in writing them have been, first, to state the facts which appear to be ascertained, and the inferences which appear to be fairly deducible from these, in regard to the functions of the living human body; and, secondly, to arrange these facts, as far as possible, in the order in which the functions, as existing in the living body, in the adult state, are dependent on one another.

I entertain a hope, that some of those, already conversant with the science, who may look into the following pages, may approve of the attempt to give a more systematic form to the subject than has been usual in most recent publications; while I am aware that others do not think the science sufficiently advanced to be taught with good effect on such a plan; and may not approve of the views, as to the connexion of the Nervous System with other parts of the animal frame, and particularly with the functions of organic

life, which are here stated, and which appear to me to justify the present arrangement.

In justification of such views on these subjects as may appear to some erroneous or premature, I can only say, that they seem to me the most legitimate inferences from the facts that are known, and to involve less of hypothesis than those to which they are opposed; and that, in many of the medical writings of the present day, I think there is a want, not so much of facts in Physiology, as of principles by which these facts ought to be connected, and by which the recollection and useful application of them may be best secured.

I have thought it right to enlarge, in these Outlines, not on the subjects which occupy the largest portions of the Lectures, but on those where, without such assistance from a text-book, the statements made in Lectures may be the most easily misapprehended; and on this account, I fear that some of the subjects here discussed may be thought more ab-

struse than I should have wished them to appear.

By the publication of these Outlines, I expect to be able to abridge considerably the time occupied in the first division of the Lectures on the Institutes of Medicine in this University; and, for the convenience of Students, I have added an Appendix, containing the Heads of the Lectures on Pathology and Therapeutics. These I hope to be able to enlarge, at a future time, into another volume, similar to the present.

I have not thought it necessary to make express reference to authorities for the statements of facts in the following pages, excepting in cases where it has appeared to me that the facts stated are not very generally known or acknowledged. In speaking of facts ascertained since the time of HALLER, I have often named the physiologists by whom they have been observed and recorded, as nearly as I can judge in the order of the originality and importance of their observations; but have

entered as little as possible into controversial discussions, especially into such as relate to the pretensions of different observers to priority of discovery ; because a much greater and more enduring interest attaches itself to the determination of truth, than to the adjustment of any such personal claims ; and because it seems to me to be one of the duties of a teacher of science, to abstain from such discussions as can have the effect of instilling any petty jealousies, or unworthy prejudices, into those minds which it is his object to train to the high task of interrogating and interpreting Nature.

ERRATA.

Page 161 line 21, *for* posterior roots of the spinal cord, *read* posterior roots of the spinal nerves,

— 211 — 18, *for* lever of the second order, *read* lever of the third order,

— 231 — 22, *for* impression on any of the senses. *read* impression on any of the organs of sense.

— 317 — 8, *for* endowments of the nerves employed in them, *read* endowments of the nerves supplying the muscles concerned in them,

OUTLINES OF PHYSIOLOGY.

SECTION I.

PRELIMINARY OBSERVATIONS.

IN treating of Physiology, we first consider the living human body when fully formed, in the adult state, and in the full enjoyment of health ; and endeavour to deliver the history and explanation, so far as is yet possible, of all that takes place in it, different from what takes place in the dead body. Afterwards we explain the manner, in which the body gradually attains to the state of perfection in which we first considered it.

In order to have a distinct understanding of the kind and degree of *explanation* of which facts in Physiology admit, and to avoid the misapprehensions and controversies which have obscured the first principles of the science, it is necessary to attend to the following considerations.

The word Life, as commonly used, does not denote an individual fact, nor a simple idea, and cannot, therefore, be *defined*. It is applied to a certain assemblage

and succession of phenomena, which are seen in a great variety of the objects that surround us, and distinguish them from the other objects of our senses. When these phenomena are examined throughout the whole of nature, it is found that the most general and characteristic of them is, the continued appropriation and assimilation of surrounding matter, which we call *Nutrition*; a process which maintains a certain definite structure called *Organization*,—which originates in all cases that can be satisfactorily observed by *Generation*,—and terminates by *Death*.

Having given this general *description* of what are called Living Bodies, we next observe, that many of the phenomena exhibited by these bodies have been found to be not only inexplicable by, but manifestly inconsistent with, the mechanical and chemical laws that regulate the changes, and have been inferred from the observation, of other departments of Nature. In so far as we can ascertain this to be the case, we say that these phenomena are effects of the *Vital Principle*, or of *Vitality*; and that is our *definition* of these terms. They are the general expression for those of the changes occurring in living bodies, which we judge to be peculiar to them; and stand in the very same relation to the science of Physiology, as the terms Chemical Affinity, Electricity, Gravitation, to other departments of Physical Science.

Thus defined, the notion of Vitality is not only admissible in Physiology, but is that which entitles it to the name of a separate science. Those physiologists, accordingly, who object to the substantive term, Vi-

tality, or Principle of Life, are obliged to use the adjective *Vital*, which conveys the very same idea.

This notion of Vitality, extending to all classes of organized beings, has no connexion whatever with the notion of Mind, as distinguished from Matter. The latter is the characteristic mark of the Animal Creation only; and requires the admission into the Physiology of Animals, of a class of facts, and a kind of evidence, that have no place in any other physical sciences. Neither does any opinion, or conjecture, that can be formed concerning the essential nature of Vitality, affect the conclusions in Natural Theology, which are drawn from physiological facts; because these conclusions do not rest on the mode in which Vitality is thought to be communicated to living beings, but simply on the observed adaptation of means to ends, in the economy of living beings.

As the phenomena of Life are seen only in bodies more or less organized, it has been conjectured that they depend merely on organization; but when we inquire how organization has been effected, we find that it implies in every instance, where we can observe it, the previous existence of vitality; and therefore must be regarded as one of its effects, not as its cause.

On the other hand, the supposition entertained by others, of a *material substance*, such as an ethereal or subtile fluid, superadded to organization during life, and producing the phenomena of life, is both unsupported by evidence, and useless in the explanation of facts.

Setting aside both these hypotheses, we hold that

all physiological inquiries are intended only to *ascertain the conditions, under which the various phenomena of Life take place*, and naturally terminate in a reference to certain *Laws of Vitality*, or ultimate facts in this department of nature; just as the investigation and explanation of phenomena in the inanimate world terminate in a reference to certain *Laws of Motion, of Gravitation, of Chemical Affinity, &c.* Of such first principles in science we can give no other account, than that they depend on the will of the *AUTHOR OF NATURE*; but the determination of such first principles is the main object, and the applications of them constitute the details, of all sciences; and every science is thus mainly conversant with principles *peculiar to itself*.

In this, as in other sciences, these general laws of nature can only be ascertained *analytically*, i. e. by the slow process of observation and comparison of individual facts; but when they have been ascertained, even partially, in this way, the information acquired is more quickly and easily communicated to others, by stating some of these principles in the outset, with short and simple illustrations, and then tracing the facts which constitute the details of the science *synthetically*; as originating, in part at least, from the operation of the laws first laid down, and then related to each other as physical causes and effects. The science of Physiology appears sufficiently advanced to be taught on this plan. The physical causes, or conditions requisite for the performance, of each of the functions, will thus appear, in part at least, from the subjects

discussed immediately before it, and its final causes or uses, from those discussed immediately after it ; and several advantages seem to arise from this arrangement, particularly in a course addressed to students, who have already acquired a considerable knowledge of Physiology in the course of their anatomical studies ; but have not been accustomed to regard the functions of the living body systematically, or as connected with a perfect whole.

The explanation of many of the phenomena of living animals is still very imperfect : but enough has been done to shew, that the principal laws regulating these phenomena must be ranked under three heads : 1. Those of *Vital Contractions*, by which the visible movements of living animals are chiefly effected : 2. Those of *Vital Affinities*, by which the chemical changes peculiar to living animals are determined, and their physical structure maintained : 3. Those of *Nervous Actions*, by which the physical changes in living animals are placed in connexion with Mental phenomena, and subjected to the control of Mental acts.

Of these, the vital affinities are perhaps the most general and the most fundamental ; but they are the least understood, and, in the higher animals at least, their exercise is dependent on internal vital contractions ; and the laws of these contractions are, therefore, properly to be considered first.

The most important division of the phenomena of living animals is into the departments of *Organic* and *Animal Life*, as distinguished by BICHAT ; *i. e.* into those which do not imply the intervention or con-

sciousness of the Mind, and those in which some act of the Mind is essentially concerned ; and the former are obviously subservient to the latter. This distinction will always be kept in view, but cannot be strictly observed ; the more complex functions (such as Respiration and Digestion) comprehending phenomena which come under both heads.

The most general of the laws which regulate the economy of animals appear to extend throughout the whole range of Creation ; and all the vital functions, as occurring in Man, may be illustrated by the corresponding functions, at least in the different divisions of the Vertebrated Animals.

SECTION II.

OF THE LAWS OF VITAL CONTRACTIONS.

THE first essential peculiarity of the Living Human Body which we consider, is the Existence of a Vital Power of Contraction in certain of its Solids; which is the immediate cause, not probably of all, but of the more conspicuous movements that take place in it during life.

We call this property or power Vital, because we are satisfied of the failure of all attempts to refer it to chemical or mechanical principles; and we regard it as an ultimate fact in Physiology, because, although other functions of the living body furnish the conditions necessary to the maintenance of the organic structures in which it resides, yet we shall find that no other functions furnish any explanation of its existence, in the structures so maintained. The following appear to be ultimate facts, or principles, that have been ascertained in regard to this power.

I. It is most distinctly seen, and has been chiefly studied, in *muscular* parts, *i. e.* in parts which consist chiefly of fibrin, and have a fibrous structure; the visible fibres being bound together by cellular membrane into fasciculi, which are generally laid pa-

rallel; and being divisible by mere separation into primary filaments, of extreme tenuity, which have the appearance, under the microscope, of rows of globules; although it is doubtful whether that appearance is not deceptive.

This general description applies both to the muscles that are subjected to voluntary efforts of mind, and to those that are exempt from such influence. But in some parts, even of the human body, such as the different vessels, some of the excretory ducts, the skin, perhaps other membranes, perhaps the lungs, and still more in lower animals, vital contractions take place in textures considerably different from this.

II. The most obvious and striking vital contractions which take place in muscles, are immediately preceded by the application of certain agents, called *Stimuli*, and necessarily *alternate with relaxation*. To the property thus indicated, the name of *Irritability* is properly restricted. When this contraction takes place, the filaments constituting the muscular fibres assume a zigzag form, the angles formed being always at the same points, and being generally obtuse, but in the case of very forcible contraction, acute: the fibres become rigid and elastic, and it would appear that they have a vibratory motion, during the continuance of the contraction; they often appear to swell out towards their centres, but experiments shew that their real bulk is not altered; the change being in the relative position, not in the size or distance, of their ultimate particles.

Even in the most distinctly irritable parts, as the muscles of the limbs, tongue, heart, bowels, bladder, there are manifest differences as to the facility of excitation, the degree, strength, endurance, and tendency to repetition, of these contractions. These differences are particularly observed in the contractions, however excited, of the muscles which are destined to Involuntary Motion, as compared with those of the muscles which are destined to be moved by the Will.

In the different classes of animals there are still greater varieties in these respects.

Various facts, to be afterwards mentioned, indicate that there is, in the living body, an *adaptation* of peculiar stimuli to the muscular action of certain organs.

III. There is, farther, distinct evidence of the existence, in certain living solids, of a vital Contractile Power, distinguished by these peculiarities, that, although liable to increase from the action of stimuli, it requires no stimulus to excite it, and hardly, if at all, alternates with relaxation, but determines a certain degree of permanent contraction, during life, of the parts endowed with it, when no distending cause affects them. This property has been called *Tonicity*. It is exemplified in the condition of the sphincter muscles during life, and in that of the arteries when emptied of blood. The extent of its operation in the living body is uncertain; but several circumstances indicate that all muscular parts possess this property, as well as

irritability. Thus, when a living muscle is divided, its cut ends retract permanently, and farther than those of a dead muscle. When a limb is permanently bent by an injury, its flexor muscles are permanently retracted, and remain capable of farther occasional contraction; and during sleep, the limbs are in a state of permanent although varied flexion, probably dependent on predominance of the flexor muscles, and implying a certain exertion of their contractile power. The temporary stiffening of the limbs after death, appears to be a last exertion of this vital power of Tonieity in their museles.

IV. The exercise of all vital power of contraction in animal Solids, is essentially dependent on the *penetration of their substance by a nutritious Fluid*, which must have been not merely absorbed from without, but in some degree changed or assimilated within the living body itself. When the supply of the nutritious fluid fails, or is vitiated, the organization of the living solids is injured, and their power impaired. And the circulation, and perhaps also the vivifying power of the nutritious fluid, is still more immediately dependent on its regular *exposure to Air*. There is great variety in different animals, as to the frequency or rapidity of the supply of this aerated fluid required for maintaining the vitality of the solids. It is on this circumstance that the essential distinction of warm-blooded and cold-blooded animals depends; and a similar difference exists in a still greater degree, in the different states of those

animals, which are sometimes in activity and sometimes torpid. The supply and the purification of the nutritious fluid are accomplished, in the order of things now established on earth, first by the living actions of the progenitor of each organized body, during the time that its own organs are gradually developed; and afterwards by the living action of certain parts of each body itself, viz. of the organs of digestion, respiration, and circulation. These conditions of the vitality of living solids, therefore, enable us to understand the necessary dependence of life on previous life, throughout all the generations of living animals; but how these conditions were fulfilled in the commencement of the existence of the first individuals of each species, nothing that we now see of their economy enables us to conceive.

V. The Irritability of many muscles is excited, not only by stimuli applied to themselves, or to the membranes investing them, but also, with equal or even greater facility, by stimuli applied to Nerves which enter them, or to certain parts of the Spinal Cord, or Brain, provided the nervous communications of these parts with the muscles be entire. It is only when a certain nervous communication between a muscle and the brain is entire, that any voluntary act of the mind excites contraction of that muscle. And farther, certain injuries of the brain or spinal cord, and certain feelings and passions of Mind (which are believed to affect these parts of the nervous system more

immediately than any other organs), have power directly and instantaneously to impair, or even destroy, the vital power of muscles themselves.

These facts have naturally led to much speculation regarding the connexion between the Nervous System and the vital power of the moving solids of the living body.

Two theories on this subject have been so generally adopted in the Schools of Medicine, that, although unsupported by adequate proof, they demand attention.

The first is, that all muscular parts *derive a supply* of some kind of *influence or energy from the brain and spinal cord*, through the nerves, which enables them to contract, or *renders them irritable*. The second is, that muscles, although not actually drawing supplies of vital power through their nerves, are yet *dependent on nerves for every occasion of the exercise of that power*—all stimuli, which excite muscles to contraction, *acting first on the nervous filaments* which enter muscles, and *through them on the muscular fibres*.

To the *first* of these opinions the following appear to be insurmountable objections.

1. Indications of a vital power of contraction are a much more general fact in nature than the existence of nerves, being seen not only in the lowest class of animals, where the existence of a nervous matter is still doubtful, but also in vegetables.

2. The human foetus has often come to the full size (implying long continued exertion of contractile

power in the organs of its circulation) without a brain, and sometimes without either brain or spinal cord ; and in all cases, during the growth of the foetus, the organs of circulation are in full operation, when the larger masses of the nervous system are still very imperfectly developed.

3. The involuntary motions of the organs of circulation have been found by many physiologists to continue vigorous, even in warm-blooded animals, after the removal of the brain, or even of both brain and spinal cord, provided that the exposure of the blood to the air is secured, by the substitution of artificial for the natural respiration (which being undoubtedly and directly dependent on the brain, necessarily ceases on its removal). And in these circumstances, when circulation after some hours does come to a stand, it is chiefly, as it would seem, because the artificial is only an imperfect substitute for the natural respiration.

4. No interruption of the contractions of the heart, or other strictly involuntary muscles, has ever been produced by cutting the nerves, by which they are immediately supplied.

5. Although the muscles destined to voluntary motion are no longer moved by the will, after the section of their nerves, they yet continue thereafter to shew their irritability, on the application of *stimuli to themselves*, or to their nerves below the section, as long as their nutrition and organization continue pretty entire ; and contractions may be excited by direct and continued irritation of the muscular fibres, fully as long in muscles of which the nerves have been cut, as

in those, the communication of which with the brain and spinal cord, through the nerves, is entire *.

Again, to the *second* of the theories above stated, it appears a sufficient objection to state, that our only reason for supposing an intervention of nerves to be concerned in muscular contraction, is the excitation of that contraction by stimuli applied to nerves. But a conclusion which is rested on this fact, must be limited to the cases in which this fact holds good. Now, there are *many muscles* (viz. all or almost all those that are destined to *involuntary motion* only), which, although exceedingly irritable, *are not excitable by mechanical irritation of their nerves*. Even Galvanism, applied exclusively to the nerves of these muscles, has generally failed to excite them; and in the instances where galvanism, so applied, has had some effect, it appears probable that the nerves acted only as conductors of the galvanism to the muscular fibres themselves. When experience shews, that some muscles are excitable by irritation of their nerves, and others not, we cannot acquiesce in the proposition that nerves furnish a condition essential to the irritation and vital action of muscles in general.

We must therefore set aside both the hypotheses above mentioned; and in so doing, we necessarily limit the meaning of the terms "Nervous Energy, Nervous Influence, Innervation," &c. in reference to the connexion of vital movements with nerves, to a

* WILSON PHILIP, Experimental Inquiry, &c. p. 99.

degree, of which many of those who use these terms do not seem to be aware.

It remains that, on this point, we acquiesce in the judgment of HALLER *, as the only generalization yet admissible, of the facts known in regard to it, viz. That the *vital power of Muscles is inherent in themselves*, and in no case dependent on Nerves; but is liable to affection in two distinct ways, by changes in certain parts of the nervous system, whether these are produced by physical or mental causes;—being *directly excited in many muscles*, and *increased or diminished, or variously altered*, probably in all *mūscles*, by such changes.

That sudden increase, diminution, or even destruction, of vital motions, may be produced by certain physical impressions, made on portions of the nervous system which are nevertheless not essential to these motions, and which may be removed from the body without stopping them, is well illustrated by the experiments of LEGALLOIS and of Dr WILSON PHILIP; and the corresponding effect of certain involuntary mental acts on muscular movements, requires no illustration. Those causes, acting on the nervous system, which augment the contractile power of muscles, and invigorate muscular motion, have been called stimuli; but are more properly called *Stimulants*, and the opposite depressing power of such causes, is expressed by the term *Sedative*.

The direct excitation of muscular contraction by changes in the nervous system, is seen chiefly, perhaps

* See particularly Elem. Physiol. lib. 17, sect. 2, § 7.

exclusively, in those muscles that are destined to be moved by the will. The increase or diminution of vital power by such causes, is seen chiefly in those muscles that are unaffected by efforts of the will. The essential difference of these classes of muscles seems to depend on the different endowments of the nerves entering them. And the final cause of all endowments bestowed on nerves in the living body, in relation to muscles, appears to be, *not to make muscles irritable, but to subject their irritability, in different ways, to the dominion of the acts and feelings of the Mind.*

VI. In all animals, and indeed in all organized beings, vital movements are seen only within certain limits of Temperature, and are stopped either by its elevation or depression beyond a certain point ; which, however, varies greatly in different kinds of animals. This difference is observed not only in the degree, but also remarkably in the permanence, of the effects of Cold on different animals ;—the vital movements in some, when once much weakened by cold, being never restored ;—while in many others, they are nearly or quite at a stand for a length of time, in the state of hybernation from cold, and are gradually resumed whenever the temperature is again raised.

Within the limits suited to each animal, it is a general principle that Heat acts as a stimulant, and Cold as a sedative, to all vital motions. But the effect either of heat or cold on these motions appears to depend, not so much on the absolute degree of tempe-

rature that is applied on any occasion, as on the amount of change undergone during its application ; and is therefore determined in a great measure by the previous state of the temperature. And this is obviously one of the reasons why Cold, itself a sedative agent, should often really and powerfully, though indirectly, invigorate muscular action ; viz. by giving a stimulant influence to subsequent applications, even of the usual heat of the body.

The vital power of muscles is also much and variously affected by other agents, particularly by Electricity, and by various Poisons, whatever the channel of communication may be, by which these agents, when applied to the living body, affect the different muscular organs.

VII. The vital power of muscles is found to undergo remarkable alterations, in consequence of the degree in which it is itself exercised. On this point, likewise, important misconceptions and erroneous theories have prevailed.

The immediate effect of frequently repeated excitation of any muscle, by physical stimuli, is a diminution, or what has been called Exhaustion, of its Irritability ; and the same effect evidently results from such repeated or long-continued efforts of the Will, as cause fatigue of the voluntary muscles. But it is by no means certain that all increased action, especially such as implies real augmentation of vital power, observed chiefly in involuntary muscles (whether from changes in the nervous system

or from other causes), is necessarily followed by any corresponding depression. The peculiar effect of poisons, such as alcohol or opium, which first augment, and afterwards depress, the action of the organs of circulation, furnishes no proof of the consequences which necessarily result from the mere circumstance of increased action itself; and in the case of exercise,—of mental excitement,—and in the course of different febrile and inflammatory diseases,—we have examples of greatly increased action in the heart, without any decidedly debilitating effect on the heart's actions necessarily following. The doctrine of increased action necessarily in all cases lowering or exhausting the irritability of muscles, particularly as applied to the involuntary motions, is therefore by no means an established principle.

In so far as the irritability of muscles is diminished by excitement, it is restored by rest; but the supposition of farther increase or *accumulation of irritability from long continued rest*, corresponding to its exhaustion by excessive action, although insisted on by various physiologists, appears to be quite unsupported by facts; and the phenomena thought to indicate such accumulation of vital power, in contractile parts kept long at rest, are explained on other principles.

Although the *immediate* effect of strong excitement of muscles is, in many cases, a diminution of their power, yet the *ultimate* effect of repeated excitement, with intervals of repose, is to augment both the bulk and strength of muscular fibres, and facilitate the subsequent excitement of moving parts, whether voluntary or involuntary. The applications of this

last principle, both in Pathology and Therapeutics, are very important.

VIII. The Vital Power of muscles undergoes gradual alterations during the whole progress of life, being most easily excited, or shewing the greatest degree of *mobility*, in young animals; becoming gradually stronger, but less easy of excitation, in adults; and afterwards undergoing a diminution both of strength and of mobility. But as these variations are attended by gradual alteration of the organization of the moving parts, it is probable that the primary change is in the vital affinities, by which these are nourished and maintained, rather than in the vital power, by which they are animated.

The movement of the fluids, in all the higher classes of animals, is in a great measure dependent on vital contractions in certain of their solids, and may be therefore regarded as the first and most important consequence of the exercise of the Vital Power which we have considered. This subject naturally divides itself into two parts; *first*, the movement of the mass of blood in the heart, arteries, and veins, or the Function of Circulation; and, *secondly*, the continual evolution of matters from, and absorption of matters into, the mass of blood, or the Functions of Nutrition, Exhalation, Secretion, and Absorption; to which the function of circulation is subservient, and on which all the other functions are dependent.

SECTION III.

OF CIRCULATION.

A REGULAR supply of nutritious fluid, recently exposed to the air, is a condition essential to the maintenance of the vital phenomena, not only in the moving solids, as already stated, but in all other parts of living bodies, whether belonging to the organic or animal life, and in all classes of animals. But it is important to bear in mind, that it is only in the higher classes of animals that this essential condition of all vital action is fulfilled by means of a Circulating System;—the nourishment even of complex structures, in the class of Zoophyta, and in many of the Articulated animals, being effected, as is believed, simply by imbibition and transudation through porous solids.

The circumstance in the animal economy, which appears chiefly to impose the necessity of a distinct circulating system, is the appropriation of a separate organ to the office of regularly exposing the fluids to the air; and this again is demanded by such occasion for strength and solidity in certain parts of the frame, as precludes the possibility of free admission of air to the fluids, in all parts of the body. A separate respiratory organ, and a regular circulating system, are therefore very generally, if not necessarily, combined through-

out the animal creation *. And in all warm-blooded animals, the circulating system is to be regarded as merely the channel of communication between the capillaries of the lungs, where the blood is prepared for the maintenance of the different functions of life, and the capillaries of the rest of the body, where it is applied to the support of these different functions. The collection and concentration of the blood at the heart are manifestly intended to subject it to the action of a strong muscle, and thereby determine its transmission, with adequate force and precision, through the different sets of capillary vessels; and the juxtaposition of the two portions of the heart, which move the blood to and from the lungs, appears to be merely a matter of convenience.

In treating of the Circulation, we first state the course followed by the blood in the living body, with the evidence by which this course is demonstrated; and then we consider the nature and efficacy of the agents, by which this movement of the blood is produced.

During the living state, all the blood which is contained in very minute or Capillary Vessels, in every part, and in almost every texture, of the body, gradually makes its way into Veins, and along them, passing from those that are more numerous and smaller, into those that are less numerous and larger, till it reaches the anterior or right auricle of the Heart, by the *venæ cavæ* and coronary vein, and distends that cavity.

* CUVIER, *Lec.* i. Art. 4. ; and *Lec.* xxiii. Sect. ii. Art. 5.

By the contraction of this auricle it is driven into the right ventricle, and by the contraction of this, into the pulmonary artery, by the numerous branches of which it is distributed among the minute capillaries of the Lungs, to be exposed to the air. From these, it again passes along an ascending series of vessels contained in the lungs, until it emerges from them to enter the four pulmonary veins, which lead to the cavity of the posterior or left auricle of the heart. By the contraction of this auricle, simultaneous with that of the right auricle, it is forced into the left ventricle; and by the contraction of this, simultaneous with that of the right ventricle, it is forced into the Aorta, by the numerous branches of which it is gradually conveyed into the capillaries, that pervade the various organs and textures of the body.

That this is the real course of the blood, is proved by various facts, but especially by the following:—

1. By the observation of the successive distension of the *venæ cavæ* near the heart, the auricles, and the ventricles, in living and warm-blooded animals, taking place in the order above stated,—and by the observed passage of the blood through these cavities, in those lower animals that have hearts similarly formed (although single) and translucent.

2. By the observed passage of the blood from the minute capillary arteries into the beginnings of the veins, in the translucent textures of different fishes and reptiles, which have a circulating system similarly formed to that of the higher classes, although single.

3. By the structure of the valves, at the heart and

in the veins, necessarily prohibiting, or greatly impeding, movement along the vascular system in the opposite direction from that above stated.

4. By the effect of ligatures, and of punctures made above and below ligatures, in the larger arteries and veins; the former swelling out and giving a free jet of blood within the ligatures, and the latter beyond them.

5. By the quantity of blood which may be rapidly discharged from a wound below a ligature on the vein of a limb; which is so great as to demonstrate that the vein must have a continual supply of blood from the arteries of the limb.

6. By the effect of injections into living arteries and veins, making their way readily, and easily filling the vessels, when thrown in the direction of the circulation as described, but strongly resisted when forced in the opposite direction.

The structure and actions of the Heart, the chief muscular agent in this process, first demand our attention. Its oblique position within the pericardium, in the fore part and left side of the thorax,—its irregular conical form, flattened posteriorly,—its division into two parts by the septum, and the form, size, and relative position of the right or anterior, and of the left or posterior auricle and ventricle,—the termination of the great veins in the auricles, and origin of the great arteries from the ventricles,—the lining of the muscular texture of the heart by two serous membranes, the external reflected from the inner layer of

the pericardium, and the internal continuous with that which lines the bloodvessels,—are all supposed to be made known by the study of Anatomy.

The muscular fibres of the auricles of the heart are quite distinct, and easily separable (after long-continued boiling) from those of the ventricles; and the part of the heart which may be regarded as the fixed point or pivot of its movements, is the point between the posterior groove on its surface and the origin of the aorta, where the muscular fibres, constituting the septum of the auricles, are set upon those which form the septum of the ventricles. The contractions, both of auricles and ventricles, tend to bring all other parts of the heart nearer to this fixed point. The texture found at this point is tendinous; and in immediate connexion with it, are the tendinous rings (partly bony in some animals) which surround the origin of the aorta and pulmonary artery, and the openings between the auricles and the ventricles. From these tendinous parts most of the fibres, constituting the muscular parietes of the heart, take their origin. Those which go to the parietes of the auricles ascend, form loops around these cavities, of various form and size, and then descend to be inserted into other points of the same tendinous rings, and are encompassed at their lower part by more superficial horizontal layers of fibres. Those which go to the parietes of the ventricles have an oblique course downwards, and appear to be reinforced by others which originate in the muscular texture itself, especially along the anterior and posterior grooves, which lodge some of the coronary vessels.

The outermost of them converge towards the apex, and, after making a spiral turn round it, pass inwards and ascend along the interior of the ventricles, forming the columnæ carneæ and part of the septum, and arranging themselves in the reticulated form, which is obvious on opening the heart. Others of the fibres descending from the tendinous rings merely form loops around the ventricles, and reascend to the rings. The obliquity of the direction of the fibres is gradually altered towards the interior of the muscular substance, so that about the centre of the thickness of the parietes, the fibres are wrapped round the ventricles nearly transversely; some surrounding both ventricles, while others detach themselves at the septum, and surround the left ventricle only, making its parietes thicker and stronger than those of the right.

This is a general outline of the disposition of the greater part of the muscular fibres of the heart. At its base the arrangement is more complex, but it is always regular and uniform; and evidently such, that a general contraction of the fibres shall bring all parts of the heart towards the central point above mentioned, and compress the contents of all the cavities, so as to secure their forcible ejection by the openings there situated.

The valves placed at these openings effectually prevent any reflux of the blood that has been ejected. The structure of the membranous folds forming the semilunar valves, at the mouths of the great arteries, sufficiently indicates their use; for they are attached to the interior of the vessels by curved edges, the con-

cavity of which is turned from the heart, and they must therefore be raised and stretched across the opening by any fluid passing towards the heart, but are laid down along the sides of the arteries by any fluid passing out of it. The precise object of the structure of the tricuspid and mitral valves which descend from the tendinous rings surrounding the auriculo-ventricular orifices, into the ventricles, and are attached by tendinous cords to the ends of the columnæ carneæ, there situated, is not so perfectly ascertained; it being doubtful, whether the membranous parts of the valves always project into the cavities of the ventricles, and are merely pulled together by the contraction of the columnæ carneæ to close the orifices, or whether they are raised and stretched across the orifices by the blood at the time when the ventricles are full, and contract on their contents. This question cannot be decided until it be ascertained, whether the contraction of the columnæ carneæ take place precisely at the same time as that of the other fibres of the ventricles. But either in the one way or the other, these valves are certainly fitted, and intended, to prevent any reflux of blood from the ventricles into the auricles, at the time when the ventricles contract.

When the heart of a living warm-blooded animal is exposed, the simultaneous contractions, first of the two auricles, and then of the two ventricles, may be distinguished; but, in the natural and vigorous state of the circulation, the former movement is hardly over before the latter begins; and the longest pause in the

visible contractions of the heart is that which succeeds the systole of the ventricles, and precedes that of the auricles.

The successive contractions of the auricles and ventricles are often observed to go on, for a short time, nearly in the usual way, after the heart of a living animal is emptied of its blood, or even removed from the body; so that there is obviously a tendency to the regular succession of these movements, independently of the successive applications of the stimulus of the blood to these parts.

When the ventricles contract, the apex of the heart is not only pulled upwards, but somewhat raised or tilted forwards; hence it is generally, and no doubt justly supposed, that it is during this systole of the ventricles, that the apex of the heart gives the impulse against the parietes of the chest, which is felt, in the natural state, between the fifth and sixth ribs, and which, just perceptibly, precedes the pulse at the wrist. The projection of the apex of the heart on the contraction of the ventricles, is seen even when the heart is removed from the body of a warm-blooded animal before its actions have ceased, and is, perhaps, sufficiently explained by the disposition of its muscular fibres, and particularly by the irregular cone which they form, being *flattened posteriorly*.

When the ear is applied to the human chest, over the situation of the heart, a dull and somewhat prolonged sound is observed to precede and accompany the impulse of the heart against the parietes above mentioned; and this is immediately succeeded by a

shorter and sharper sound ; after which there is a short pause, before the dull sound and impulse are renewed. A slighter impulse or succussion, is sometimes observed to accompany the sharper sound likewise. The duller sound, and stronger impulse, are generally ascribed to the contraction of the ventricles ; and LAENNEC and others have ascribed the sharper sound and feebler impulse to that of the auricles ; but this last opinion is probably erroneous ; because the sharper sound certainly immediately *precedes* the longest pause in the sounds of the heart ; whereas the contraction of the auricles immediately *succeeds* the longest pause in the visible contractions of the heart ; as appears, not only from experiments on animals, but also from cases occurring occasionally in the human body, both in health and disease, where the contractions of the right auricle are made obvious by a retrograde impulse, communicated to the blood in the jugular veins.

It is also doubtful, whether the contraction of the columnæ carneæ in the inside of the ventricles, takes place at the same instant with that of the mass of muscular fibres constituting their parietes. It is obvious, that the contraction of these columnæ cannot aid in lessening, but must elongate and enlarge, the cavities of the ventricles. It has therefore been conjectured, that their contraction may alternate with the general systole of the ventricles, and pull down and stretch the tricuspid and mitral valves during the diastole of these, and so prepare them for the entrance of the blood from the auricles ; and that the second or

sharper of the sounds of the heart, is caused by this action of the columnæ and valves. Perhaps it may also be supposed, that one stimulus which excites the columnæ to act, is the pressure made on them during the previous contraction of the mass of muscular fibres lying exterior to them, in the systole of the ventricles; and that the contraction thus beginning in those internal columns, is afterwards propagated to that surrounding mass of fibres, many of which are continuous with those in the columnæ themselves. In this manner it seems possible that the peculiar convoluted form of the muscular fibres of the heart may be concerned in giving the tendency above noticed, to a regular succession of their own contractions.

The contractions of the muscular fibres of the different parts of the heart are clearly sufficient to agitate the blood powerfully, and ultimately to eject it by the arteries with great force. The quantity ejected at each systole of the left ventricle seems to be nearly two ounces in an average-sized man, and the space it must occupy in the aorta nearly eight inches. The calculations of HALES, who states the force exerted by the left ventricle of a human heart as equivalent to $51\frac{1}{2}$ pounds, the velocity of the blood leaving the heart as 149.2 feet per minute, and the quantity of blood passing through the heart every hour as 20 times the whole weight of the blood in the body,—although only approximations to the truth, do not appear to be founded on exaggerated data. The velocity of the circulation is also illustrated by the fact, that in the horse, a fluid injected into one

jugular vein has been detected in the opposite vein and even in the vena saphena, within half a minute.*

The diastole, as well as the systole, of the different parts of the heart, especially of the ventricles, is performed with force; the muscular fibres not merely relaxing as the cavities are distended with blood, but springing back directly after their own contraction is over. The tendency thus given to the formation of a vacuum in the auricles, is, no doubt, a cause of motion of the blood towards the heart along the great veins, where it is subject to pressure from various causes.

Although the different parts of the heart have obviously a tendency to regular and successive movements, independently of the stimulus of the blood, yet we can have no doubt that the blood, which is in contact with the inner surface of the heart, acts as a powerful stimulus upon it; and that it is by the constant succession of fresh applications of this stimulus, that the nearly uniform succession of the heart's movements, throughout the whole of life, is maintained.

We can go no farther, in assigning a cause for the natural movements of the heart, than to refer them to the application of this stimulus, and to the property of Irritability, in a high and peculiar degree of intensity, resident in its fibres. We cannot ascribe to the heart any feeling or Sensation, in the performance of these actions, without altering the meaning of these words; we cannot liken these actions to any Voluntary movements, without overlooking the most essential peculiarities of both; and we cannot suppose

* HERING, *Journal de Progrès*, &c. t. 10.

any action of Nerves to be essentially concerned in them, without ascribing to the nerves of the heart endowments, which no experiments or observations shew that they possess.

The blood is conveyed from the heart to the capillary vessels all over the body by the Arteries; and the properties of these constitute the second great agent, by which its motion is effected.

These are flexible and elastic tubes, consisting of three coats, of which the exterior, composed of dense cellular texture, is the most distensible and the toughest; the middle, composed of transverse fibres, denser and lighter coloured than those of muscles, is the thickest, strongest, and most elastic; and the internal, on which the blood moves, is very thin and smooth. The arteries are all to a considerable degree extensible, especially in the longitudinal direction; and are of great strength, the smaller branches even more so than the larger.

Every small portion of artery, by reason of its elasticity, has nearly a cylindrical form, and the blood therefore passes along a series of descending cylinders, on its way from the heart to the capillaries. But the sum of the areas of the whole of the smallest branches into which any artery divides itself, is considerably greater than the area of the artery itself; although the ratio of this difference has been very variously stated.

The arteries are subdivided into small branches to a great but very various degree of minuteness in the

different textures. In some parts the smallest branches are so minute as not to admit the red globules of the blood; but various textures appear to be nourished, without so minute a subdivision of their vessels.

The smaller arteries communicate or anastomose freely with one another in all parts of the body; the smallest capillaries the most freely of all; and on this account the characteristic effect of ligatures formerly observed, in emptying the portions of artery beyond them, and distending the portions within them, is only distinctly seen in the larger branches.

The arteries in the living body (with the exception of the smallest branches, in which a greater variety is observed) are always filled, and even somewhat distended with blood, which is moving towards the capillaries. This blood receives a sudden increase of velocity from the impulse of each successive jet of blood from the ventricles of the heart; and from the same cause the arteries are slightly distended,—and in many parts of the body even somewhat displaced. These *effects of the systole of the ventricles*, constitute what is called the *Pulsation of the Arteries*; but the two last of these effects, in the healthy and tranquil state of the circulation, are scarcely perceived at any single points; and therefore the pulse in an artery is not distinctly felt, unless the artery is somewhat *compressed* by the finger, to make the impulse, which its contents receive from the heart, perceptible.

The slight distention which the whole arteries experience, from the impetus of each successive jet of blood from the heart, is sufficient to call into action

their elasticity, which enables them to react on the blood, in each interval of the heart's pulsation, and gradually to equalize its motion, until it becomes quite uniform and continuous in the capillaries.

There are many and great obstacles to the free motion of the blood along the arteries,—from the friction of their sides,—from their angular and tortuous course and minute subdivisions,—and from their constant tendency to contraction. The effect of these is, not, as some have taught, to make the velocity of the blood in the smaller arteries less than in the larger, but to make its velocity, in all the arteries, less than it otherwise would be. As we know that no part of the circulating system in the healthy state is continually becoming fuller of blood, we are sure that the quantity of blood delivered into all the veins in a given time from all the arteries, is equal to that received by them from the heart; and this proves, that the velocity of the blood in the capillaries, on the whole, must be less than that in the aorta, just in the same proportion as the area of the aorta is less than the sum of the areas of all the capillaries.

But although this proportion must hold on the whole, yet many facts inform us, that the velocity of the blood, even in vessels of the same size in different parts of the system, is habitually different; and that the quantity of blood received into, and its velocity in, the small arteries and capillaries of all parts of the body, are liable to much temporary variation. In particular, the blood which enters the brain, as it

meets with more of the obstacles above mentioned than that which is sent to most other parts, must have a habitually slower motion. For these varieties in the flow of blood in different parts, and at different times, there is ample provision, in the distensibility of the vessels, and in the possibility of increased velocity in one part compensating for diminished velocity in another, without the general law above stated being perceptibly violated.

Although the ordinary velocity of the blood in different arteries must be very different, it would appear from the experiments of POISEUILLE, that the pressure exerted on the blood in different parts of the body (as measured by the column of mercury which the blood in different arteries will sustain), is almost exactly the same.

That the pressure of the coats of arteries may act as a powerful cause of motion in the blood, appears from the effects of an opening made in an artery, in which case a current of blood is established towards the opening, from the artery and anastomosing branches beyond it, as well as from those nearer the heart; and the same is shewn by the rapidity with which the portion of an artery beyond a ligature is emptied of its blood.

The action of arteries on their contents seems to be always of the same *kind*, as that which results from the physical property of elasticity called into action by a distending force; but the following facts appear sufficient to prove that they possess the vital power of Tonicity, as formerly defined, which probably de-

termines a *greater degree* of reaction on their contents, than mere elasticity would occasion.

1. In experiments made by many physiologists, particularly by VERSCHUIR, THOMSON, GIULIO and ROSSI, PARRY, HASTINGS, and WEDEMEYER, it appeared, that by various stimuli applied to arteries, chiefly small arteries, which could not affect their mechanical properties, constriction of those arteries, at the points irritated, lasting some time, and then gradually relaxing, were induced.

2. In experiments made by WEDEMEYER, it was found, that when stimulating fluids (such as alkohol or vinegar of a certain strength) are injected into the arteries of living animals, there is great difficulty in pushing them forward into the veins, whereas mild fluids in the living body, and these irritating fluids in the dead, pass forward readily *.

3. In experiments made by Mr HUNTER and Dr PARRY, it appeared distinctly that the arteries of dying animals, especially those dying from hæmorrhage, when emptied of their blood, contract immediately after death, and in some instances before death, to a caliber considerably less than that which they afterwards gradually assume, and then maintain till putrefaction begins; which proves, that the tendency of living arteries to contraction is greater than their merely physical properties can occasion.

4. In experiments made recently by POISEUILLE, where an artery from an animal just killed was distended by water, urged by the pressure of a given

* Edinburgh Medical and Surgical Journal, vol. xxxii. p. 10.

column of mercury, and then the force of its reaction measured by the height of a column of mercury which the water expelled from it could support, it appeared that the force of reaction, excited by the distention of the recent artery, was greater than the force used to distend it; and greater than an artery could exert some time after death, but before any decomposition of its texture had commenced *.

These facts leave no room for doubt that arteries possess, and must occasionally, if not habitually, exert on their contents a truly vital power of contraction.

This being ascertained, we next observe, that various facts shew the course of the blood to be variously modified, and probably much promoted on the whole, by causes acting at a distance from the heart;—in modes which the merely physical properties of arteries cannot possibly explain. The most instructive of these facts are the following:

1. The great amount of the obstacles which oppose the free flow of the blood into and through the small capillaries of the system; and the force therefore found requisite in the dead body to imitate the flow of blood by injection, especially when injection is attempted in an animal just killed, when, as it would appear, the property of tonicity remains in the bloodvessels.

2. The small amount of force found sufficient to stop the flow of blood along the chief artery of a limb, when compared with these obstacles, which the

* MAGENDIE, *Journal de Physiologie*, t. 8.

blood, moving along that artery, must encounter in its passage through the smaller vessels*.

3. The immediate effect produced on the flow of blood through the arteries of a limb, in some cases of Palsy, in which the heart's action is unaffected.

4. The greatly increased determination of blood to various organs at particular times, without corresponding alteration of the heart's action; *e. g.* in many cases of partial inflammation or hæmorrhages,—in the case of blushing, and other effects of mental emotion,—in the case of occasional or periodic secretion or nutrition at individual parts, whether natural or morbid, often observed without increase of the heart's action,—and contrasting strongly with other instances, where, from mental emotion, exercise, febrile disease, &c. the heart's action is strongly excited, while secretion and nutrition are every where diminished.

5. The alteration which is gradually produced on the arteries of any part of the body, when any cause is applied, which greatly and permanently augments the action going on at *their extremities only*; the influence of which cause is manifestly *retrograde* along the vessels;—*e. g.* the increased size given to the anastomosing branches of a limb, of which the principal artery has been tied,—when contrasted with the shrunk condition of all the arteries of the stump of a limb which has been amputated;—the increased size and tortuous course of the arteries of the uterus during gestation, and of the arteries of any part of the

* CHARLES BELL, Essay on the Powers that move the Blood.

body, where the growth of a tumour has been excited*.

These facts shew, that the flow of blood in the arteries, and especially in the capillaries, of different parts, bears no fixed relation to the state of the heart's action.

Two questions, however, remain for consideration :
1. Is the action of the heart, although not the sole agent, essential to the motion of the blood, in all parts of the system? 2. How far is the additional power, which plainly affects the motion of the blood, at a distance from the heart, referable to the vital contractions of the coats of arteries?

I. It appears from experiments of different physiologists, and especially of MAGENDIE, that when the circulation of a limb, in a warm-blooded animal, is confined to the branches of a single artery and corresponding vein, the blood stagnates in the vein, whenever the artery is emptied by ligature; but flows freely along the vein, when the ligature on the artery is removed; which shews that the action of the capillaries and veins of a limb is insufficient to propel the blood, without the impulse *a tergo*, given by the heart and large arteries. Indeed a little management gives nearly similar results in a common bloodletting.

Farther, the movement of the blood in all the small vessels of a warm-blooded animal, is always speedily arrested when the heart's action ceases; and although

* CHARLES BELL, *loco citato*.

there are various examples on record, in which the human foetus (always imperfect, however, in other respects), has attained a considerable size without a heart, yet every such foetus has been contained in the same womb, and probably nourished through the same placenta, as another foetus of the natural structure; and in every such case the heart of the perfect foetus would, in all probability, be instrumental in maintaining the circulation of the monster. It would appear, therefore, that in warm-blooded animals at least, the heart's action is essential to the support of the circulation in every part of the vascular system.

II. The influence exerted on the circulation by any action of the *larger* arteries is certainly inconsiderable; because the circulation has often been observed to be well maintained, when those arteries had become rigid and inflexible, and lost both their elasticity and vital power. But the vital properties of arteries probably reside chiefly in their *smaller branches*, as would appear from the following facts:—

1. From the coats of the smaller arteries bearing a much larger proportion, on the whole, to their fluid contents, than those of the larger.

2. From the fibrous coat of the smaller arteries more nearly resembling muscular texture.

3. From experiments of Mr HUNTER, which shew that the smaller arteries contract more at the moment of death than the larger.

4. From many experiments of BICHAT, BUNIVA,

PARRY, &c. which shew that an injection thrown into the arteries immediately after death, while tonicity remains in them, passes by the largest of the arteries that communicate with veins, but does not fill the smaller capillaries ; and from the observation of HUNTER, that an injection forced into the arteries of an animal just killed, which retain their tonic power, is apt after a time to be forced back into the larger.

5. From the observation of HALLER and others, that in animals just killed, and of which the hearts have been cut out, the blood in the arteries as well as the veins is apt to move chiefly from the smaller to the larger branches*.

It cannot, therefore, be doubted that this vital power of the smaller arteries must, to a certain degree, modify the motion of the blood ; but it has been questioned whether *an increase* of this tonic power can, in any case, promote the flow of the blood ; and it has been supposed that it is by a *relaxation* of this kind of contraction, giving additional effect to the impetus from the heart, that local determinations of blood are effected.

To this opinion there are the following objections :

1. The amount of the obstacles already noticed to the flow of blood in the arteries, renders it probable, that whatever vital powers affect the motion of the blood, at a distance from the heart, must on the whole assist, instead of opposing, the effect of its contractions.

* Memoires sur le Movement du Sang, p. 160.

2. If local and occasional congestions of blood resulted simply from diminution of the vital action of the arteries, allowing a fuller effect to the impulses given from the heart, the blood in the capillary arteries of congested parts might be expected to have always an intermitting motion, which is not the case.

3. The causes which usually excite local congestions of blood, are very generally causes which, in all other instances, *excite*, instead of depressing or weakening, vital action.

But although these statements render it probable that vital contractions, chiefly of the smaller arteries, do come in aid of the actions of the heart in maintaining and regulating the circulation, yet we have no evidence of any powerful action of this kind being habitually exercised ; and the following reasons may be given for thinking that causes distinct from any vital contractions of vessels, are concerned in producing the flow of blood in the extreme branches of the arteries.

1. The smallest arteries, or true capillaries, in which the greatest variety as to the quantity and velocity of the blood is observed, do not shew any fibrous structure ; and when the circulation in them is examined with the microscope, in ordinary circumstances, no contractions of their coats are perceptible.

2. HALLER and others have described varying movements of globules of blood in living animals, such as do not appear to be explicable by mechanical laws, seen under the microscope, when these globules had

escaped from the bloodvessels into surrounding textures *.

3. Movements of other fluids contained within living textures, and even of fluids placed in contact with living textures, have been observed, which cannot be traced to the influence of any contractions of solids †.

4. On minute examination of the progressive development of parts in the foetal state of different animals, it appears that various parts are in progress of organization (implying regulated movements in the fluids) before the heart acts, or the arteries are distinctly formed ‡.

When the blood has been delivered into the capillary vessels of any living part, although no doubt still influenced by the contractions of the heart and arteries, it must be supposed to come likewise under the dominion of the laws, whatever these be, by which the movements of the nourishing fluid are effected, in those animals that have no circulating system, and in vegetables. In particular, it may fairly be presumed, that the *Vital Affinities*, which regulate the chemical changes that are wrought on the blood in the

* DOLLINGER, Journal de Progrès, &c. vol. ix. SCHULTZE, Journal Complementary, &c. vol. xix.

† DUTROCHET, L'Agent du Mouvement Vital dévoilé, &c. and Annales des Sciences Naturelles, t. xv. GRANT, Edin. Phil. Journal, vols. xiii. & xiv. SHARPEY, Edinburgh Medical Journal, vol. xxxiv.

‡ BAER in BRESCHET's Repertoire 1818. PREVOST and DUMAS, Annales des Sciences Naturelles, t. 12.

capillaries, must likewise be a cause of its movement there. To this we should probably refer the striking fact (to be afterwards more fully considered), that when the chemical changes at the lungs are arrested, by obstruction to the access of air thither, the contractions of the right ventricle and pulmonary artery, although continuing vigorous for a time, fail of their wonted effect; and the blood stagnates in the capillaries of the lungs and right side of the heart; but its motion is instantly resumed, if, within a short interval of time, the access of air to the blood be again permitted.

Since it has been ascertained that Galvanism, transmitted through a fluid, is a cause, not only of its decomposition, but of its movement, through any porous substance, from the positive towards the negative side of the apparatus, it has been conjectured that the electrical relations of arterial and venous blood, may be an important cause of the motion of the blood in the capillaries*. But if this be a cause which promotes, as has been stated, the flow of blood in the capillaries throughout the body, where the arterial blood becomes venous, it ought to retard its motion in the capillaries of the lungs, where the venous blood becomes arterial. Yet we know, from the fact just stated, that the change of the blood from venous to arterial at the lungs, is a very powerful cause of its motion there.

The power or property, by which various fluids attract others with unequal force, through the interven-

* REUSS, Comment. Societ. Physico-Medicæ Moscov. vol. 1.

tion of any porous substance, lately described by DUTROCHET and others under the names of Endosmose and Exosmose (in whatever way it is to be explained), must no doubt operate as a cause of motion in the fluids in different parts of the animal system. But neither this, nor any other principle, which is found to apply equally to dead matter, can suffice for the explanation of the *variations*, especially of the sudden and partial variations, observed in the motion of the blood in the capillaries in different parts, and in different circumstances of the body; for example, of those which result from mental acts or feelings. Whether the auxiliary powers, residing in the small arteries, consist merely in contractions of solids, or partly in *peculiar attractions* of solids and fluids, we cannot doubt that they are in a great measure truly *vital*.

No termination of arteries has ever been distinctly demonstrated, except that in Veins. This is seen on microscopical examination, in the translucent parts of various living animals, and may be traced, after injection, in different textures of the human body. The capillary arteries which are turned backwards and form veins, vary considerably in size, some admitting three or four globules of blood abreast, and others probably not admitting one.

The veins become gradually, though not uniformly, larger when traced towards the heart, and terminate ultimately in the venæ cavæ or coronary vein. Those which are of sufficient size to be examined, are found to consist only of two coats, corresponding to the out-

ermost and innermost of the coats of arteries, but possessed of greater strength. Hence they are thinner and less elastic, but more distensible and tougher, than the arteries. Near the heart, and in various other parts of the larger veins, thin irregular layers of fibres, more or less resembling those of muscles, are interposed between their coats.

The veins in the extremities, and generally in muscular parts of the body, are provided with valves, constructed nearly in the same manner as those at the mouth of the aorta, with their free edges towards the heart.

There are two important singularities in the venous system; *first*, The Sinuses within the cranium, formed by separation of the laminae of the Dura Mater, into which the veins of the Pia Mater open obliquely in a direction opposite to the current of the blood, and the effect of which is to lessen the effect on the vessels of the brain, of any stagnation and congestion of blood in the great veins near the heart; *secondly*, The distribution of the Vena Portæ, (which is of great size and strength, and collects the blood from the stomach, intestines, pancreas, and spleen), through the substance of the liver. In many of the lower animals, the venous blood from the lower extremities is, in like manner, diffused through the kidneys *.

Besides being more distensible, the veins are considerably more numerous and more capacious than the

* JACOBSON, Edin. Med. Journ. vol. xix.

arteries, and their larger branches anastomose much more freely. Hence the quantity of blood in the veins is always much greater, and is liable to greater variations, both locally and generally, than that in the arteries.

From the smaller capacity of the arteries, and from the pretty uniform distention, on the whole, of all parts of the vascular system, it follows, that the velocity of the blood in the veins must, on the whole, and in the same proportion, be less than that in the arteries. And, from the sum of the smallest veins of the body having a much larger capacity than the *venæ cavæ*, it follows, that the velocity of the blood in these largest veins must, on the whole, and in the same proportion, be greater than that in the smallest veins. But the circumstances stated as to the structure of veins, admit likewise of greater local and temporary variations of the velocity of the blood in them, without perceptible deviation from these general laws, than can occur in the case of the arteries. Absolute stagnation, and even retrograde movement, for a time, of blood in individual veins, have often been observed in experiments on animals.

The ordinary motion of the blood in the veins is continuous, with these exceptions, *first*, That, in a state of great weakness, when the arteries are very little distended by the stroke of the heart, the blood in the smallest of the veins retains somewhat of the intermitting motion; *secondly*, That the flow of blood in the great veins, even independently of disease, is slightly retarded at each systole of the auricles, and

accelerated on their diastole ; *thirdly*, That the flow of blood in the great veins is somewhat retarded by each act of expiration, and accelerated by each inspiration ; the natural effect of the enlargement of the shut cavity of the chest, in inspiration, being to draw towards it, (*i. e.* to cause the pressure of the atmosphere to urge towards it), not only air by the trachea ; but also blood by the great veins. This last is the Respiratory Pulse of HALLER and others, which is distinctly seen to communicate a movement to the brain and spinal cord, when they are exposed.

The motion of the blood in the veins is manifestly determined by various causes.

1. Probably the most efficacious is the impulse *a tergo* communicated by the heart and arteries, the effect of which is unequivocally shewn by the experiment mentioned at page 38. But when we consider the *very moderate degree of distention* of the veins in the living and healthy body, and their *great distensibility*, we cannot doubt that causes different from this must habitually co-operate.

2. The experiments of several physiologists, particularly VERSCHUIR, HASTINGS and BECLARD, seem sufficiently to indicate a vital power of Tonicity in the veins, similar to what we ascribed to the arteries. But in several parts of the body, as in the interior of bones, and in the substance of the liver, where the coats of the veins form the internal lining of unyielding canals, it is obvious that this power cannot be exerted ; and in any individual part it is probably a feeble power.

3. Gravitation manifestly affects the flow of blood in the veins, especially of the extremities ; but cannot materially, on the whole, promote the flow towards the heart.

4. The action of neighbouring muscles, and probably the pressure of other adjacent textures, such as the skin, aided by the effect of the valves, frequently and greatly promote the flow of blood in many veins, chiefly of the extremities.

5. It appears that the " suction influence" of the diastole of the auricles of the heart, promotes the flow of blood along the veins more than their systole retards it *. But the rapid distention of a vein below a ligature, where this cause cannot act, shows that the other causes of the motion in the veins are much more powerful.

6. It appears, from the experiments of Dr BARRY, that the motion of the blood along the veins is promoted also, in animals of which the respiration is similar to the human, by the " suction influence" of the acts of inspiration above mentioned. But, besides what was observed in the last paragraph, the facility with which circulation is carried on in the fœtus, which does not breathe ; in animals, of which the pericardium has been opened, and the heart exposed to the air (so that no influence of this kind can affect the motion of the blood) ; and even in cases of artificial respiration, where no such influence can be exerted by

* See particularly WEDEMEYER in Edin. Med. and Surg. Journal, vol. xxxiv. p. 89.

the chest—sufficiently demonstrates that this cause likewise is of comparatively inconsiderable amount.

The effect of the more violent respiratory actions on the flow of blood in the veins, and particularly the retardation of the blood's motion, and congestion in the great veins, from forced or prolonged expiration, accompanied by muscular effort, are very important in Pathology. Muscular exertion, especially of the respiratory muscles, has the additional effect of accelerating the flow of blood in the arteries, which will be considered afterwards.

The Pulmonary Artery and its branches are similar to the other arteries of the body, and the pulmonary veins to other internal veins. The termination of the smallest branches of the artery in the capillary veins of the lungs, has been ascertained as distinctly, and in the same manner, as in other textures; and the smallest branches of the bronchial arteries, which bring arterial blood from the aorta, have been found to inosculate with those of the pulmonary artery.

As the whole of the pulmonary circulation is carried on within the cavity of the chest, it cannot derive any aid, on the principle of suction, from the movements of the chest. But the motion of the lungs in inspiration and expiration promotes the flow of blood through their substance, for reasons which will appear afterwards.

The fibrous middle coat found in the pulmonary artery and its branches, as well as in the aorta, is

probably chiefly useful by resisting the strong and variable impulse given by the heart's contractions, and thus preventing morbid dilatation of the arteries. And it is with the same intention, no doubt, that the great veins are strengthened by muscular fibres near their termination, where they are exposed to the retrograde impulse from the stroke of the auricles.

According to the most probable estimates, the whole quantity of blood in the body may be in general about 1-5th of the weight of the whole body, and of this, it is generally thought that about 1-4th may be in the arterial, and 3-4ths in the venous system.

SECTION IV.

OF THE COMPOSITION AND PROPERTIES OF THE
BLOOD.

THIS subject demands attention before we can proceed to state the uses of the Circulation.

The Blood in the living body, or immediately on emission from the vessels, consists of a clear fluid, in which a very great number of red particles are suspended. Its specific gravity is about 1050, and its temperature about 98°. Within a few minutes after emission, in the natural state, it divides itself into a yellowish fluid called *Serum*, and a dark red spongy mass called *Crassamentum*.

In some cases, chiefly morbid, the crassamentum is spontaneously divided into two parts, the *colouring matter*, which lies lowest, and a whitish tenacious substance called *Fibrin*, which covers its surface. And in all cases, this division of the crassamentum into two parts may be accomplished, either by carefully stirring fresh drawn blood with a stick, to which nearly all the fibrin, and little of the colouring matter, adheres; or, more completely, by repeated affusions of cold water and pressure, by which the colouring matter is carried off and the fibrin left.

Of the three substances into which the blood is thus divided, it has been generally believed that the Serum and Fibrin are combined *in the clear fluid* of the living blood, and that coagulation depends on their separation, and on the red globules attaching themselves more or less completely to the fibrin. But the microscopical observations of PREVOST and DUMAS* lead them to believe, that the fibrin is combined with the colouring matter *in the globules* of the living blood, and that coagulation consists in the adhesion of the globules to one another, with more or less complete separation of these, their constituent parts.

Until it be more clearly ascertained what is the true relation of the fibrin to the other principles in the living blood, the account we can give of this fluid is necessarily very imperfect. And farther, when we state the chemical composition and properties of these or any other animal substances, two cautions must always be kept in mind.

1. The proximate principles which are procured from these substances, have not necessarily existed in them just in the form in which they appear, but may be in part the products of the chemical operations, however simple, by which they are shewn.

2. As we know that the peculiar combinations of Carbon, Hydrogen, Oxygen, and Azote, which form the animal principles, tend continually to dissolution, and cannot be recomposed by art, we have reason to believe that the chemical affinities of these elements are some-

* Ann. de Chimie, tom. xviii. and xxiii.

how modified, in those vital actions in which the animal principles are formed ; and until we know something of the Laws according to which chemical affinities are controlled and altered in the living body, we cannot expect that the chemical examination of dead animal matter will give much assistance to Physiology.

The following are the most important results of Chemical Examination of the three substances into which fresh drawn blood divides itself :

1. The serum has a specific gravity of about 1030. When it is heated to 160°, an abundant coagulum of *Albumen* is formed in it, just similar to that which is formed in the same way from the glaire of the egg. This coagulated albumen once formed from either fluid, is insoluble in water,—soluble, by the aid of heat, in the caustic mineral alkalies,—is formed into a substance resembling gelaten by the long-continued action of acetous acid, or diluted nitric acid,—and is little prone to putrefaction.

The fluid which drains or may be expressed from coagulated serum is called the Serosity. It consists of water holding in solution a little of an uncoagulable animal matter, which has been called Muco-extractive ; which shews itself on evaporation, is soluble both in water and alcohol, and may be precipitated by acetate of lead ; and also a little of the following salts,—Soda or its Sub-carbonate, Muriate of Soda, Sulphate and Muriate of Potass, and Phosphates of Lime, Magnesia and Iron. The proportions of these different ingredients in the serum are,

Water,	-	-	-	-	900
Albumen,	-	-	-	-	87
Muco-extractive,	-	-	-	-	4
Salts,	-	-	-	-	9
					<hr/>
					1000

2. The *Fibrin* has a peculiar tendency to assume the fibrous form. In chemical relations it differs very little from coagulated albumen *. Both are resolvable, as the products obtained from them by the full action of heat shew, into Carbon, Hydrogen, Oxygen, and Azote, and the difference between them lies in the fibrin containing rather less oxygen and more azote. The proportions have been thus stated,

	Carbon.	Hydrogen.	Oxygen.	Azote.
Albumen,	52.8	7.5	22.8	15.7
Or, -	17	13	6	2 atoms.
Fibrin, -	52.3	7.0	19.6	19.9
Or, -	18	14	5	3 atoms.

3. The colouring matter is quite insoluble in the serum, but readily unites with water, as is shewn by the means of separating it from the fibrin. The solution, or intimate mixture, of this matter in water is acted on by heat nearly as serum is; and the solid matter deposited from it, does not appear to differ materially from coagulated albumen, except in colour, and in yielding a small quantity of oxide of iron, not only when burnt, but, after the application of chlorine, by its liquid tests.

4. Carbonic acid is usually disengaged from fresh drawn blood, but in variable, and generally very mi-

* HATCHETT, Phil. Trans. 1800. BERZELIUS, View of Animal Chemistry.

nute quantity : in some cases it is not obtained, even by the action of the air-pump.

A small but very variable quantity of fixed oil is often suspended in the serum, and thought by some to exist always in the blood.

The colouring matter, although it cannot maintain the solid form without the assistance of fibrin as a cementing medium, and although it is probably impossible to separate it completely from the other constituents of the blood, is generally thought to constitute the greater part, and the densest part, of the crassamentum ;—its quantity has been stated at nearly ten times that of the fibrin, in a portion of crassamentum properly dried ; and its specific gravity as 1126 or 1130, that of the whole crassamentum being 1077 or 1084 *.

In order to ascertain the comparative quantities of the solid matter of the serum, and solid matter of the crassamentum, in blood, it is necessary to evaporate slowly to perfect dryness, first a given weight of the serum, and then of the crassamentum, and weigh the residuum in each case ; and then to allow as much of the residuum, in the second experiment, to be solid matter of the serum, contained in the crassamentum, as the results of the first experiment shews to be the proportion in pure serum, corresponding to the quantity of water that has been driven off. The remainder of the residuum only, is the weight of the solid matter of the crassamentum itself. The average result of trials

* DAVY, *De Sanguine*. Edin. 1814.

made in this way gives these proportions in human blood

Water, - - - - -	784
Solid matter of Crassamentum, -	129
Solid matter of Serum, - - -	87 *
	<hr/>
	1000.

Of the whole blood, therefore, more than one-fifth is solid matter, and of the solid matter nearly three-fifths are in the crassamentum.

The proportion of solid matter of the crassamentum in the blood is found to vary remarkably according to the quantity drawn, when that is considerable, —being much less in the last drawn blood than in the first; probably because the evacuation of blood causes the return into the larger vessels of much of the thinner part of the blood, previously diverging into the smallest capillaries †.

The Globules of the blood in the living body, whether they contain the fibrin in their composition or not, possess singular properties. They contain the whole colouring matter, though in varying proportion. They have, in every species of animal where they exist, a determinate form, circular and flattened in man, and a uniform size, stated at from $\frac{1}{3000}$ to $\frac{1}{5000}$ of an inch in diameter in man. They have such tenacity as to regain their form and size after being compressed

* PREVOST and DUMAS, *Annales de Chimie*, t. 23.

† DAVY, *De Sanguine*, Edin. 1814. SCHRÆDER VAN DER KOLK *Commentatio De Sanguine Coagulante*. Groningen, 1820.

and flattened, as they sometimes are in narrow blood-vessels; and when at rest tend to arrange themselves in somewhat determinate forms *. But these properties they seem gradually to lose after they are removed from the living body.

The phenomena of the coagulation of blood, whether dependent on a change in the aggregation of the matter composing the globules, or on the separation of the fibrin from the serum, demand consideration. This change generally begins in two minutes, and extends to the whole mass in six or seven, after blood is drawn, but the cohesion of the coagulum formed continues to increase often for many hours after. It consists in the fibrin becoming concrete, and assuming a reticular form,—in the interstices of which the colouring matter is lodged,—and then gradually contracting; and as the fibrin is of somewhat less specific gravity than the colouring matter, the coagulum appears first, and is firmest, at the upper part.

The coagulation of blood is not attended with any decided elevation of temperature, nor is it necessarily, although frequently, attended by any evolution of carbonic acid. It is promoted by heat, by exposure to air, and by rest or gentle agitation only, but is not prevented by the opposites of these. It takes place very slowly, even when blood is at rest, in the living body. It is promoted by separation of the particles of blood from one another on a flat surface,

* PREVOST and DUMAS, *Annales des Sciences Naturelles*, t. 12.

even *in vacuo*; and more remarkably by an increase of the serous part of the blood; and this is the reason why blood drawn from the veins of persons weakened by loss of blood, or fainting, or of dying animals,—being, as already observed, more serous,—coagulates much more rapidly than the blood drawn previously *. From this cause the last blood drawn from the vein of an animal bled to death may coagulate almost instantly, while the blood in the large vessels of the same animal may be found fluid after death, and then coagulate slowly.

Two distinct peculiarities of the blood, as to its disposition to coagulate, are often observed, both in disease, and in other circumstances of the body. These are most commonly seen in very different states of the body, but are not opposed to each other; and in a few cases even coexist with one another. The *first* is, the state in which coagulation is imperfect, and the coagulum formed unusually large, loose, and flocculent. This is observed after violent muscular exertions, and in various diseases, particularly those which arise from a virulent contagion or malaria, and are attended by typhoid symptoms. The extreme case of this condition of the blood is its perfectly and permanently fluid state, where no separation of its constituent parts takes place, and all the fibrin is found in minute particles diffused through the mass; and this is seen after sudden death, from suffocation, from blows on the stomach, diseases of the heart, light-

* DAVY, Thesis 1814. SCHRÆDER VAN DER KOLK, l. c.

ning, muscular exertion, or mental emotion;—likewise after the most rapidly fatal diseases, such as tetanus, or the worst forms of fever.

The *second* peculiar state of the blood as to coagulation is, where the fibrin and colouring matter separate from one another, as well as from the serum; of which the extreme case is, the formation of the firm thick buffy coat seen in various inflammatory diseases. This does not depend on the circumstance of slow coagulation of blood, and consequent separation, by gravity, of the colouring matter from the fibrin, but on an unusual tendency to separation between these substances; of which there are two simple proofs. 1. That the formation of the buffy coat (though no doubt favoured or rendered more complete by slow coagulation) is often observed in cases where the coagulation is more rapid than usual; and the colouring matter is even observed to retire from the surface of the fluid in such cases, before any coagulation has commenced. 2. That the separation of the fibrin from the colouring matter in such cases takes place in films of blood, so thin as not to admit of a stratum of the one being laid above the other;—they separate from each other laterally, and the films acquire a speckled or mottled appearance, equally characteristic of the state of the blood, as the buffy coat itself*.

It does not appear possible to explain the fluidity of the blood in the vessels of the living body, the phe-

* SCHRÆDER VAN DER KOLK, Commentatio, &c.

nomena of its coagulation when emitted, the variations of this progress now mentioned,—and especially the modes in which these variations are produced,—by reference to any mechanical or chemical principles; and if not, then it becomes incumbent on us to ascribe Vital Properties to the Blood as it exists in the living body, as well as a vital character to the processes by which it is formed. (See p. 52.)

As the aggregation of the particles of the fibrin in the coagulum, when once produced, continues until putrefaction begins, it would seem, on first consideration of the subject, sufficient to ascribe the fluidity of the blood during life to its vitality, and coagulation to the loss of vitality. But, on the other hand; the varieties observed as to this aggregation of the fibrin, and as to its separation from the colouring matter, and the total absence of any such tendency in the cases where coagulation never takes place,—as they appear inexplicable by any mechanical or chemical principles,—would seem to indicate that the act of coagulation itself is a last exertion of the vital properties of the fibrin; and it has accordingly been likened to the stiffening of muscular fibres after death. However, these two processes are not, as has been supposed, necessarily connected with each other; the stiffening of muscles being well marked in some cases where the blood remains fluid after death.

Intestine movements of the particles of blood among themselves may be seen in various circumstances, and have been minutely described by different

microscopical observers*. These have been judged to be vital, and to be concerned in producing its fluidity; and coagulation has been considered as the last effort of the powers, by which these movements are effected. But although this supposition seems probable, it has not been ascertained that these visible movements in the blood are inexplicable by merely physical laws.

The vital properties of the blood probably reside in its globules, which seem to differ from any thing seen in unorganized matters; and more especially in the truly coagulating part of the blood, *i. e.* the fibrin; and their existence there is still more clearly indicated by the changes which fibrin effused from the vessels in inflammation undergoes; for it has been ascertained that it is in pure fibrin effused from this cause, much more than in coagulated entire blood, that new vessels are formed, and organization established†.

The varieties observed as to the formation and properties of this effused and organizable lymph, in different diseased conditions of the body, are likewise, in all probability, indications of its vital properties, and of changes to which these are liable.

Arterial blood has been ascertained to differ from venous not only in its colour being scarlet, instead of purple, but also—

1. In coagulating both more quickly and more firmly.

* TREVIRANUS, SCHRÆDER, SCHULTZE, DU-TROCHET, &c.

† THOMSON on Inflammation.

2. In the crassamentum formed in it, and especially the fibrin of that crassamentum, bearing a larger proportion to the whole blood*.

These peculiarities, after what has been stated above, naturally lead us to suppose that the vital properties will exist in arterial more than in venous blood; and accordingly, it is with the circulation of arterial blood through the different textures, almost exclusively, and with the separation of portions of the arterial blood in them, that the other vital phenomena of the living body are connected.

* According to PREVOST and DUMAS, about 1 per cent. more. See also SCHRÆDER VAN DER KOLK.

SECTION V.

OF NUTRITION, EXHALATION, AND SECRETION
IN GENERAL.

ALTHOUGH the existence of arterial branches, terminating in exhalant surfaces, in secreting organs, or in the solid textures, has not been proved* ; and although the observation of the actual escape of particles of blood from the circulating vessels, and their application to any of the animal textures, has been described by very few microscopical observers, and may be held liable to fallacy ; yet the following considerations leave no room for doubt, that portions of the circulating blood are continually applied to the formation and support of the solids and other fluids of the body, and that, in so far as these are dependent on such supplies, they receive them from the blood.

1. The formation of many of the fluids, and some of the solids of the body, is continually going on ; as that of all parts of the body is, during the time of growth. There is also good evidence, to be afterwards stated, of continued absorption from all parts of the body, without loss of substance, which implies continued deposition.

* MASCAGNI De Vasis Lymphaticis.

2. While these facts show that something is continually added to the solids, and other fluids of the body, it is equally clear that something is continually abstracted from the blood; because continual additions are made to it from the organs of digestion, without permanent increase of its quantity; but this is quickly diminished when those supplies fail.

3. The blood is continually applied to the solids, and to the prepared fluids of the body, in capillary vessels which must easily admit of transudation; and is materially changed by that application.

4. The blood is fitted, by its composition, for supporting the different animal solids and fluids; and we have actual proof of its application to these purposes, in the case of increased exhalation or artificial dropsy, produced by injection of water into the vessels, in many experiments of MAGENDIE and others; and in many cases of wounds healed, swellings formed, or adhesions contracted, evidently by blood or lymph effused from vessels in a state of inflammation, and becoming organized.

5. Increased growth, natural or morbid, of any part, is always attended by great enlargement of its vessels, and the vascularity of those textures, in which fluids are continually formed, is always much greater than that of those, in which solid matter only is contained.

The term *Nutrition* is generally applied to the deposition of solid matter from the blood, and the term *Secretion* to the formation of fluids; this last being divided into *Exhalation*, where the fluid is

thrown out on an extended surface, and Secretion properly so called, when it is prepared in a gland, and carried off by a duct.

All that is known of the course of the portions of blood destined to these purposes is this : It passes, in all these cases, in numerous capillary vessels, with very thin coats, not to be distinguished from the surrounding textures, along the surface of membranes, along the septa of cells, or in the interstices of fibres. A membrane, on which many vessels ramify, seems all that is necessary to any kind of secretion ; and all the varieties of secreting organs to be only “ contrivances for conveniently packing a large extent of such a surface in a small compass *.” These vessels, so far as they can be traced, either in the living bodies of animals, or after the most successful injections with size and vermilion, pass on to the veins. It is very doubtful whether the particles of vermilion ever escape from them except by rupture ; and any extravasations from them in the natural state, would seem to be, not through visible outlets, but by *lateral pores* †.

It is an important question, whether the different textures and secretions of the body are actually *formed* from the circulating blood, at the parts of the body where they appear, or are formed in the blood itself, and only *evolved* or separated at these parts. The following facts seem to favour the last opinion :

1. It is a general law of living animals, and pro-

* MAYO.

† MASCAGNI, SCHULTZE, DU-TROCHET, PREVOST and DUMAS, &c.

bably of vegetables* also, that all nourishment received from without must be mixed with secretions of the organized body itself, and so far elaborated in its interior, before it is applied to the support of any part of the organization; which makes it probable that an important part, at least, of the process which fits it for giving that support, is completed before it reaches the organs where it is so applied.

2. As the blood contains, or shews, after the simplest chemical processes, Fibrin, Albumen, Muco-Extractive Matter resembling Osmazome, Water, perhaps an Oil, the phosphates of Lime and Magnesia, and most of the other salts found in the secretions, it appears fitted to yield, by mere separation of its constituent parts, by far the greater part of the substances found in the textures and secretions of the body.

3. There are various instances, in disease, not only of textures widely extended over the body, such as Bone and Fat, being deposited in unusual situations, but also of substances usually secreted in special organs only, such, for example, as Cholesterine, being deposited in parts distant and very different from those where they are commonly found; and, even independently of structural disease, there are various well authenticated cases on record, where secretions, especially those of urine and of milk, have been thus established and passed off, for some time “*per aliena cola* †.”

* See KNIGHT, Philosophical Transactions, 1805.

† Setting aside, as inapplicable here, many of the cases recorded under this head by HALLER (*Elem. Lib. 7. C. 1.*), there remain several which seem to justify this observation; and various

4. It has been ascertained, first by PREVOST and DUMAS, that, when the secretion of urine is suppressed by extirpating the kidneys of animals, the Urea, which is the characteristic part of that secretion, may, after a time, be detected in the blood ; and the same has been found in the human body, in some cases where the secretion of urine has been much obstructed by disease of the kidneys *.

But, on the other hand, it is to be observed,

1. That a conclusion resting on observations made on the secretions of urine, bile, and milk, which are destined to excretion, is not necessarily applicable to the case of those formations from the blood which are destined to useful purposes in the animal economy.

2. That it is doubtful whether the Fat of the animal body, or the Nervous Matter, can be recognized in the Blood, and certain that the Gelatin, which is easily procured in abundance from many animal textures, cannot be recognized there ; and several of the other elements of the animal textures, found in small quantity in the blood, may be supposed to be the products of *Absorption*.

3. That in Insects and Zoophyta, where secretion and nutrition are seen in their simplest forms, the general nourishing fluid, formed and contained in one

similar cases have been recorded since, *e. g.* in MAGENDIE's *Journal de Physiologie*, vol. vii. ; and *London Medical and Physical Journal*, June 1828.

* BOSTOCK's *System of Physiology*, vol. iii. p. 412. CHRISTISON, *Edinburgh Medical and Surgical Journal*, vol. xxxii. pp. 271 and 274.

internal cavity, appears to furnish a variety of products very different from itself, by a process hardly more complex than mere transudation through a living membrane*.

These facts lead us to believe, that, although some of the products formed in the living body are so far elaborated in the blood itself, yet, in various instances, a material change is effected in these products at the time and place of their escape from the circulation.

It has been doubted, whether Transudation takes place at all through textures in the living body, and been supposed that all Secretion and Nutrition must be by branches of arteries specially designed for that purpose ; but the occurrence of transudation through living textures, which was maintained by Dr W. HUNTER and by MASCAGNI, has been put beyond doubt by the experiments of MAGENDIE and others. It appears, however, that it takes place to a less extent than in the dead body : and the escape of fluids from the vessels, in particular, must be impeded, and may no doubt be variously modified, by the exercise of their tonic power, formerly considered.

There has been much farther speculation as to the explanation of the formation of so many different compounds in the living body from the same blood ; but inquiries on this subject have led to results, which, though very important, are for the most part negative.

I. The blood, in its passage to the different organs, is propelled through canals of extreme minuteness, va-

riously contorted, and of very various length, and endowed, perhaps variously, with the power of acting mechanically upon it; and the frequent alterations of the distances and positions of its particles, thus effected, have been supposed to be a sufficient cause for the variety of products which it yields. But the insufficiency of this explanation is shewn by the following facts.

1. It appears from the cases mentioned, that Secretions may pass out for a time, by organs distinct from those at which they generally appear, and this without perceptible change of structure, or subsequent alteration of the functions, of the parts that take on this new kind of action.

2. Substances the most widely different in composition from the blood, such as Bone and Cartilage, are formed in parts of the body where there is no very complex arrangement of vessels; and very complex arrangements, in various parts, yield products but little different from the serum of the blood.

3. Even in different parts of the human body, and still more on examination of various animals, it appears, that products very nearly resembling each other, and answering the same ends, are formed in organs where the structure and the disposition of the vessels are very various; and again, that substances the most widely different are formed in organs that are in these respects extremely similar*.

* CUVIER, Leçons, t. 5. p. 214.

II. As Secretion is much influenced by causes acting on the Nervous System, and especially by injuries there inflicted, it has been and still is supposed by some physiologists, that it is necessarily dependent on some power communicated through the nerves from the brain and spinal cord. But to this theory of *dependence* on the brain and nerves, the following appear nearly insurmountable objections.

1. Secretion and Nutrition are phenomena observed much more generally in nature, than any vestiges of nervous matter; viz. not only in those animals where no nervous system has been detected (which must be allowed to be a doubtful case), but in the whole vegetable kingdom.

2. Secretion and Nutrition take place after the usual manner, in the case of the human foetus without a brain,—in that of the foetus without either brain or spinal cord,—nay, even in the foetus which has hardly a vestige of nervous matter in its composition*.

3. It appears from the inquiries of different anatomists, and particularly of TIEDEMAN and GMELIN, and of SERRES, that the formation of the larger masses of the nervous system in the foetus, is always posterior to many acts of nutrition and secretion; and that vessels ramify, and different textures are already nourished in every part, before nervous matter is distinctly formed there.

4. Such injury or disease of the nervous system as destroys all voluntary motion and sensation of a limb, and materially affects the pulse there, although it

* CLARK in Phil. Trans. 1793.

usually modifies, does not stop the nutrition or the secretions there, nor prevent the usual effects of inflammation, which are analogous to secretion, from taking place; and in different experiments of physiologists, when the nerves of secreting organs were cut (*e. g.* of BICHAT on the Testicle, and MAYO on the Kidney), secretion in these organs, although sometimes altered, was not suspended.

In opposition to these facts, the experiment (familiar to HALLER, but often repeated and varied by Dr WILSON PHILIP and others), of cutting the 8th pair of nerves in the neck, and thereby arresting the digestion of food, which implies suspension of the secretion of the stomach, is surely too slender a foundation for the general assertion, that a nervous influence is essential to all Secretion.

Farther, the conclusion thus drawn from that experiment is liable to the following objections:

1. The result of the experiment is not uniform; for the trials of BRESCHET and EDWARDS, and more especially those of LEURET and LASSAIGNE*, seem sufficient to establish the positive fact (necessarily much more conclusive in this inquiry than any negative fact), that, after the section of those nerves, with loss of substance, in the neck, and without the aid of galvanism, digestion may, in certain circumstances, be carried on.

2. The secretion at the stomach is peculiarly under the influence of mental emotions and sensations; and

* Recherches pour servir à l'Histoire de la Digestion, p. 133.

the effect of this operation is not only to cause pain, but to excite much nausea and dyspnœa, which are fatal within two or three days. Such sensations, however caused, will materially affect that and other secretions, without proving the necessary dependence of the secretions, on the parts by the injury of which they are caused. When the branches of the 8th pair going to the stomach were cut on the œsophagus by MAGENDIE, the effect on the lungs and the dyspnœa not being produced, the secretion at the stomach was not arrested.

3. In all experiments made by cutting the nerves in the neck, it has appeared, that while the secretion at the stomach was suspended or diminished, the secretion in another part, equally supplied by these nerves, viz. the bronchiæ, was *greatly increased*.

4. In Dr WILSON PHILIP'S experiments, the secretion of the stomach, suspended by the operation in the neck, was restored by Galvanism. The result is therefore conclusive *against* any influence from nerves being essential to secretion, unless it were proved that nervous influence is identical with galvanism. Now this is not proved; and if it were, it would give little assistance in explaining secretion; because galvanism is a *single* known chemical agent, and the difficulty is, to explain the evolution of *many and various* chemical compounds, in different parts of the body, from the same blood.

III. The reference made by BICHAT, of the phenomena in question, to the property which he called

Organic Sensibility, and likened to Sensibility properly so called, is also quite unsatisfactory; because the term sensibility, and all principles connected with it, are inapplicable to changes which are unattended by any Sensation.

It appears, on the whole, beyond doubt, that the phenomena of Secretion and Nutrition are inexplicable by, and inconsistent with, any principles that can be deduced from the observation of dead matter, or of other functions of the living body. At the same time, it is obvious that they do not take place fortuitously, or at random, but according to fixed laws. We refer them, therefore, to a Vital Property, our notion of which is, as yet, necessarily vague and imperfect;—which modifies chemical affinities in the living body;—varying in different parts of the body, and causing these to be differently affected by, and produce different effects on, the blood that pervades them;—influencing likewise, no doubt, the chemical nature and relations of the blood itself. To this property, the best name that has been given is VITAL AFFINITY. Its existence will no doubt always be an ultimate fact in Physiology; but the limits of its agency, and the laws according to which it modifies the chemical relations of the substances subjected to it, may no doubt be ascertained; and their development will probably constitute the next great discovery in this Science.

Several well-known facts, besides the phenomena of secretion and nutrition themselves, in the mean time, illustrate the general principle, that the vessels, and

the powers that move the blood in the vessels, in different organs and textures of the body, are differently affected by the blood that pervades them, or by substances conveyed to them by that blood. Of this kind are,

1. The difference, already mentioned, between the flow of arterial and venous blood through the vessels of the lungs, while both pervade with ease the substance of the liver.

2. The fact, that textures which shew nearly an equal degree of vascularity after fine injection in the dead body, habitually admit very different quantities of blood in the living body*.

3. The specific effects of various poisons, and contagious effluvia, circulating on the blood, in individual glands or individual membranes only.

The widely different effects of various substances (*e. g.* of Air) applied externally to the vessels of serous and of mucous membranes, is no doubt to be referred to the same general principle.

* See BICHAT, Anat. Gener., tom. ii. p. 479.

SECTION VI.

OF ABSORPTION.

THAT Absorption, both of solids and fluids, takes place frequently, and to a great extent, in the living body, is easily proved,

1. By the wasting of the whole body, or of individual parts of it, which no external agents can affect, observed in various circumstances of health and disease.

2. By the disappearance, whether spontaneous or determined by art, of fluids which had been perceived in various parts of the body, or been injected into the cavities of the body.

3. By the effects produced by various substances placed in contact with any living surfaces, exactly similar to those produced by them when received into the stomach or injected into a vein.

We first state what is known of the agents by which Absorption is effected, and afterwards endeavour to estimate the extent to which it is carried on in the living body.

The vessels called Absorbents were, for a time, thought to be the only agents, and are still thought to be important agents, in this work of absorption.

These vessels are similar in appearance to the smaller veins, but are of more delicate texture; their

coats are not distinctly divisible into different layers, but are very distensible, tough, and elastic. They are also more fully provided with valves, and of more irregular diameters, than the veins. Their smaller branches anastomose very freely, and are very numerous in many textures of the body; but there are some textures, as the Bones, in which they can hardly be traced, and others, as the contents of the Cranium and the Nervous System generally, in which they have not been detected. They are divided into the Lacteals, which come from the intestines, and the Lymphatics, which come from other parts of the body. The origin of the lymphatics has never been distinctly demonstrated in warm-blooded animals; but in fishes, where they have no valves, anatomists have satisfied themselves, by injection, that they have open mouths on the surface of membranes. The origin of the lacteals by little openings in the villi of the internal membrane of the intestines, has been seen in a few cases, as by CRUIKSHANKS and MAGENDIE, when they were distended by chyle.

In the human body, all the vessels which can be distinctly recognized as lacteals or lymphatics, pass somewhere through the small oval-shaped bodies called Conglobate Glands, most of which are set together in clusters in the hams, groins, axillæ, on the sides of the neck, in the posterior mediastinum, beside the iliac arteries and aorta in the pelvis and abdomen, and in the mesentery. Several branches of these vessels enter and pass out of every such gland; and they are so intimately subdivided and reunited within its substance

that every branch leaving it appears to be in communication with every branch that entered it.

Every gland is likewise fully supplied with blood from arteries, which are minutely subdivided, and convoluted within it. It is doubtful whether any of the lymphatics leaving a gland can be injected from the arteries entering it, without rupture; but that some intermixture, by transudation, of the contents of these minute vessels within the glands must take place, can hardly be doubted. And according to the observations of Mr ABERNETHY *, the organs in the whale, which correspond to mesenteric glands, are so constructed as to ensure a perfect intermixture of the contents of all the vessels entering them.

These vessels unite after the manner of veins, and, when traced to their termination, lead to two points in the vascular system; those where the internal jugular and subclavian veins meet, on each side of the neck. The trunk, which terminates here on the left side of the body, has its chief supply from the thoracic duct, which ascends beside the aorta in the abdomen and thorax, from the vertebræ of the loins. But it is now ascertained, by the observations of ABERNETHY †, BRACY CLARK, TIEDEMAN, FOHMAN, LAUTH, LIPPI, PORTAL, and others, that in Man, and others of the Mammalia, vessels which have the characters of lymphatics, and pass through glands, occasionally terminate in the veins in their own neighbourhood.

* Phil. Trans. 1796.

† Ibid.

The contents of the lacteal vessels will be considered under the head of Digestion. The fluid contained in the lymphatic vessels of animals, and in the thoracic duct of those that have fasted long, has been found very various in quantity, and somewhat various in qualities; but in general, of fully as low specific gravity, and containing as little animal matter, as the serum of the blood, and nearly resembling it in chemical composition; with these remarkable differences, however, that a number of globules, similar to those of the blood, are observed in it; and that it contains a small quantity (not more than .005) of fibrin, and therefore coagulates when emitted. It has sometimes a reddish colour, and becomes florid on exposure to air, especially in animals that have fasted long. In such animals it is most abundant; but where weakness has been brought on by inanition, its quantity is again diminished*.

That the movement of the fluid contained in these vessels must be towards the great veins, is shewn by the structure of the valves, which will not admit of motion in an opposite direction, unless the vessels are much dilated. Although the motion is slow, the fluid is propelled with force. The vessels contract and empty themselves when punctured; and when the thoracic duct has been tied, it has generally been ruptured by the distention below the ligature †.

* COLARD DE MARTIGNY in "Journal de Physiologie," 1829.

† Sir E. HOME, Phil. Trans. 1811.

Supposing all these vessels to arise (as all allow the lacteals to do) by open mouths, from the surface of membranes, the interior of cells, &c. the principle of Capillary Attraction is a sufficient cause for the ascent of fluids along them; but the influence of this cause alone can never call into action the elasticity of the vessels, to promote that ascent; because the effect of capillary attraction is fixed and uniform, and, in order that the elasticity of a tube may be a cause of motion in its contents, it is necessary that the other forces propelling these should be variable or intermitting.

Neither can the ascent of the fluids contained in these vessels, in so far as it depends on capillary attraction, be aided by the action of the valves; because a fluid drawn up into a set of tubes by this cause alone, has no tendency to recede; and the only use of a valve is to prevent recession of fluids.

The structure and the elasticity of these vessels, therefore, and the principle of capillary attraction, are quite inadequate to explain the momentum, which the facts above stated show, that the contents of these vessels in the living body possess; and no other cause can be assigned which, on merely mechanical principles, will explain these phenomena. We are therefore constrained to believe, that the fluid in these vessels is moved by powers which are strictly Vital; but how far vital contractions of the vessels may suffice for the explanation of this motion, or how far, as in the case of the capillary circulation, other vital powers may be supposed to operate, is doubtful.

We shall see reason to think, likewise, that some

of the absorbent vessels take up certain fluids in preference to others, and even of others of which the particles are smaller; and for this preference, it is obvious that the principle of capillary attraction offers no explanation.

Some doubt has been thrown over the general opinion as to the origin of Lymphatics strictly so called, from the general uniformity of their contents, and from the fact, of their frequently receiving a part of injections thrown into arteries. But the following reasons may be given for thinking, that the whole of this system of vessels is engaged in the work of absorption.

1. The whole of these vessels are constructed exactly alike, and they lead to the same termination; and the origin and absorbing power of the lacteals is undoubted.

2. Although these vessels have often been filled by matters injected into arteries, yet, after the most minute and successful injections made by MASCAGNI with size and vermilion, and where no rupture of vessels could be detected, it was found that the matter existing in these vessels was only the colourless size, which had transuded on the surface of membranes, and into the cellular texture; and *this colourless size was found in these vessels only*, all vessels which contained coloured matter being traced to arteries and veins; so that the evidence of these injections favours the belief that the lymphatic vessels are not continuous with arteries, but may be filled by any matters that are effused from arteries.

3. The well known morbid phenomenon, of those lymphatic glands very frequently becoming inflamed which lie in the course of the lymphatic vessels leading from ulcerating surfaces (where it is certain that absorption is going on, and where noxious substances are often absorbed from without) strongly indicates that it is through these vessels, at least in part, that this process is carried on.

4. In some cases, a striking correspondence has been observed by MASCAGNI and others, after death, between the contents of the lymphatic vessels of parts of the body and various morbid effusions or secretions existing at those parts *.

The absence of any peculiar matters from the *larger* branches of the lymphatics, remarked by ANDRAL and others, in many subjects where extensive suppurations or other effusions had existed, is not decisive evidence against this doctrine; particularly as it is known that the contents of these vessels are often moved forwards, after most of the functions of life have ceased.

But we have now satisfactory proofs that the function of Absorption is carried on likewise by Veins, and to a much greater extent than the small number of vessels having the character of lymphatics, which have been found to terminate in the smaller veins, can explain.

* See particularly MASCAGNI *Vasor. Lymphat. Historia*, p. 20. The most important cases recorded by him are not noticed in the commentary on this passage by MAGENDIE.

The experiments of HUNTER, made by exposing and isolating small portions of the intestines of living animals, filling them with different fluids, chiefly milk and a solution of indigo, and then examining the contents of the lacteals, and of the veins leading from these, may be allowed to prove two points: *1st*, That absorption, at least of milk, and probably of other fluids, different from chyle, took place in his trials by the lacteals; *2dly*, That no absorption could be ascertained, in his trials, to have taken place by the veins.

The first of these, which is a positive observation, although opposed to the results obtained by MAGENDIE and others, agrees with the results of many other experiments, by LISTER, HALLER, BLUMENBACH, TIEDEMANN and GMELIN, LAWRENCE and COATES, and FODERA, in which it appeared that a certain portion of different fluids, introduced into the intestines, was taken up by the lacteals; and the possibility of their absorbing fluids different from chyle may, therefore, be held to be decided. But the second observation of Mr HUNTER, which is a negative one, is quite an insufficient ground for the general conclusion, that veins do not absorb; and the reality of venous absorption is now put beyond all doubt, by the positive observation of many physiologists, particularly by the following.

1. The experiments of Sir E. HOME and Mr BRODIE * prove, that when the great lymphatic

* Phil. Trans. 1808.

trunks are tied in warm-blooded animals, substances injected into the stomach quickly find their way into the circulation, and may be detected in the urine.

2. Experiments made by MAGENDIE, FLANDRIN, TIEDEMANN and GMELIN, and others, prove that odoriferous substances, known by their smell, and saline substances, indicated by their tests, after being taken into the stomach, are detected in the veins on the mesentery, both larger and smaller, and in the vena portæ, much more than in the lacteals and thoracic duct.

3. Experiments made by MAGENDIE, prove that a poison introduced into an isolated portion of intestine, communicating with the rest of the body only by an artery and vein, or into the cellular texture of a similarly isolated limb, acts in the usual way, and nearly in the usual time, when the circulation is free.

4. In experiments made by SEGALAS, it appeared that a poison introduced into a portion of intestine between two ligatures, failed of effect as long as the artery and vein leading to that portion were tied, although the lacteals and other textures were uninjured, but took effect as soon as the circulation was set free*.

5. In experiments made by Professor MAYER, it appeared that saline substances introduced in small quantity into the bronchiæ of animals, found their way very quickly into the blood, although the thoracic duct was tied, and were detected in the left side of the heart much sooner than in the right side†.

* Journal de Physiologie, 1822.

† Bibliothéque Universelle, Jan. 1818.

6. In experiments by FODERA *, it appeared that two saline solutions, applied to the inner and outer membrane of an isolated portion of intestine in a living animal, *were united in the small veins* leading directly from that portion of intestine.

7. In experiments by MAGENDIE, it appeared that a poison applied to an isolated vein, with all precautions to avoid contact with other textures, or even to an isolated artery, gradually transuded into the interior of the vessel, and then produced its usual effects.

8. In cases of disease where large deposits of morbid matter have taken place within a short time,—in cases of Suppuration, of Fungus Hæmatodes, and of Melanosis, the veins of the affected parts have been found loaded with the morbid matter, more generally than the absorbents.

It would appear, therefore, that the veins are concerned in the function of absorption in all the following ways:—1. They themselves absorb, chiefly by their smallest branches, at least fluid matters. 2. The contents of the lacteals and lymphatics are probably partially intermixed with those of the veins in lymphatic glands. 3. Some of the smaller lymphatic trunks terminate in veins. 4. The largest lymphatic trunks terminate in the great veins of the neck.

From the inner membrane of the intestines, it would seem, from the observations of many experimenters, that the absorption of thin fluids is chiefly by veins, and that of the chyle, which is a thicker fluid, by the open mouths of the lacteals only.

* Recherches Experimentales sur l'Absorption et l'Exhalation.

Two facts of much importance may be stated here, as natural consequences of absorption, in most parts, taking place chiefly by transudation into the interior of vessels, in which a current of blood is continually flowing.

1. That the absorption is much diminished by unusual fulness of the sanguiferous vessels, and increased by their inanition, as appeared particularly in experiments of MAGENDIE, where the effects of poisons introduced into cavities of the body were observed, first after an artificial plethora had been induced by injections of water into the vessels, and then after the vessels had been partially drained of their blood.

2. That absorption from any surface of the body is much diminished, or suspended, by greatly diminishing the pressure of the atmosphere on the part, as by the action of a cupping-glass in many experiments of Dr BARRY.

That absorption of the fluids of the body is continually going on, is evident from familiar facts ;—as to the contents of the Alimentary Canal, from the disproportion between the ingesta and egesta ; as to the Fat, from its diminution in consequence of fasting ; as to the Bile and Urine, from their higher colour and greater density when they are long retained ; as to the Contents of the Thorax and Abdomen, from the rapid disappearance of any fluid introduced there artificially, &c.

That a continued Absorption of the solids of the

body likewise takes place, is concluded chiefly from the following considerations.

1. The same kind, and nearly an equal amount, of supplies from without go to the blood during the adult state, and when the solids are apparently stationary in bulk, as during the period of the most rapid growth.

2. The penetration of the solid textures by arterial blood is necessary to preserve them from putrefaction, and it seems probable that this preservation is effected by a perpetual change of their particles.

3. In various circumstances, both of health and disease, absorption of animal solids is easily caused, and shews itself unequivocally ; *e. g.* in the muscles in consequence of rest ; in all textures, and especially in the Bones, in the decline of life ;—in the Thymus Gland after birth ;—in the Uterus after delivery ;—in the gradual alteration of the form of several bones and other organs, both during their growth, and in the subsequent progress of life ;—in the gradual diminution of the size of various organs, by *interstitial absorption*, in consequence of fasting, and of different diseases ;—and of almost all organs, by *progressive absorption*, when they are subjected to unusual pressure from tumors or abscesses ;—and in the process of Ulceration. In all these cases, as the vascular organization of the parts, in which the increased absorption is going on, undergoes no material change, it cannot be supposed that the vessels have assumed an unwonted office.

There is, however, great variety as to the facility and rapidity of absorption in different textures. The

permanence of the marks on the surface of the body produced by gunpowder, and by tatooing, and the long duration of the colour produced by the full internal use of nitrate of silver, sufficiently indicate that the renewal of the particles of the true skin is a very slow process. But the facts stated leave no room for doubt, that those of the animal solids which are provided with vessels, and are dependent for their properties on the constant flow of blood through these vessels, are subject to a continual although slow process of absorption and renewal of their particles.

SECTION VII.

OF THE PROPERTIES OF THE TEXTURES AND
SECRETIONS FORMED FROM THE BLOOD IN
THE LIVING BODY.

THE different Textures and Secretions which are formed from the blood, are the materials, which are variously combined in the constitution of the different sets of organs, the functions of which are considered in the other departments of Physiology; and a knowledge of the *general anatomy* of these is essential to a right understanding of the uses to which they are applied. We introduce here, therefore, a short summary, in regard to each texture, *first* of its merely physical properties, the purposes these serve, and its distribution over the body for these purposes; *secondly*, of its chemical properties and composition; and, *thirdly*, of the vital phenomena it exhibits, and the peculiarities of any secretions that may be formed in it.

Almost all the solid textures have appeared to several observers, under the microscope, to consist ultimately of minute globules, of the same size with those existing in the blood. But the investigations of Mr BROWN and Dr HODGKIN render it doubtful whether that appearance is not deceptive.

The knowledge of the chemical composition of the different textures, and the fluids formed in them, gives

at present but little assistance, either to their Physiology or Pathology ; but will no doubt assume a greater importance, when we shall have more precise ideas as to the modifications which chemical principles undergo in living bodies.

The strictly vital phenomena presented by most of the textures, are nearly confined to the vascular parts included within them ; but the most important vital properties of some of the textures, particularly the muscular and the nervous, reside evidently in parts exterior to the vessels.

We omit, for the present, all mention of the sensibility of the different textures ; that being in fact a part of the Physiology of the Nervous System.

We consider here, first, those textures which have originally a cellular structure, and may be made to shew somewhat of that structure by maceration in water ; and afterwards those which shew a fibrous, but not a cellular structure.

I. OF BONE.

This, the hardest and densest of the animal solids in man, as in other vertebrated animals, gives the general form to the body, and the requisite strength and support to many of its parts. It gives protection to the most important viscera, and firm attachments to most of the muscles, and to ligaments, tendons, and fasciæ ; and the articulations of the different bones are essential to most of the muscular movements.

All the bones are composed of laminae, so arranged as to form cells, which in the long bones have the form of minute longitudinal canals. All have a firm investing membrane externally, and a more delicate membrane lining the cavities in their interior, in which the medulla is lodged. There are important differences as to the arrangement of the cellular structure in different bones. The external parts are the most compact; in the short and flat bones, the internal cellular structure is pretty uniform; whereas the broad extremities of the long bones of the limbs are composed of a spongy texture throughout, and their narrower shafts have a thicker compact structure externally, and a long cavity in their interior. By these arrangements these bones have sufficient strength, combined with lightness; their articulating ends have sufficient breadth; and they give both sufficient room for the fleshy bellies of the muscles, and advantageous attachments for their tendinous extremities.

The bones consist of earthy and animal matter, which are intimately incorporated, even in the minutest particle of their substance*. The earthy matter constitutes nearly 2-3ds of their weight. It consists almost entirely of Phosphate with a little Carbonate of Lime. These may be freed from the animal matter by burning bone, or they may be dissolved from it by diluted muriatic acid, and successively precipitated from the solution by Ammonia, and Carbonate of Ammonia.

* See GORDON'S System of Anatomy, p. 253, and CRAIGIE'S General and Pathological Anatomy, p. 531.

When bone has been deprived of all its animal matter by the action of fire, it retains its hardness, but has become brittle and inelastic; when all its earthy matter has been extracted by acid, it retains its form, but has become soft and flexible.

Two animal principles are contained in, or may be easily procured from bone,—Gelatin and solid Albumen. The gelatin is obtained by the long continued action either of diluted muriatic acid or of boiling water; and by the continued application of these agents, particularly by water heated under pressure to above 212° , its quantity is so much increased, that it is probably in part formed by the process. The albuminous contents of bone remain after both these processes.

The Gelatin which is procured from bones and from various other animal textures, by these means, is distinctly characterized by its ready solubility in hot water, and its forming a tremulous mass when cooled, by its solubility in diluted mineral acids, by combining with caustic alkalies, but not forming a compound like soap; by the copious precipitate it forms with the vegetable astringent principle called tannin; and also, by being more putrescible than the other animal principles already mentioned. It differs from the others chiefly in containing more Oxygen, and less Carbon, its analysis being,

Carbon.	Hydrogen.	Oxygen.	Azote
47.8	7.9	27.2	16.9

These differences may give us a general idea of the manner in which this substance may be formed in

the living body, from the albuminous contents of the blood.

The effects of injury, and particularly of fracture of bones, the effects of pressure, from whatever cause, exerted on them, and the effects of various diseases, sufficiently indicate, that the vital processes of nutrition and absorption are performed in this texture with activity; and may go on to a greater extent than in almost any other texture, although they take place more slowly than in many of the soft textures.

But the vessels that can be traced into the substance of bones are minute; and their nutrition is very dependent on the vascular membranes which invest them internally and externally, and on which their vessels ramify, until they are much reduced in size. Hence the destruction of either of these membranes causes always the death, at least of the adjoining portions of bone; and in the reparation of bone the adjoining soft textures are always, although not exclusively employed.

The nutrition of bone takes place chiefly beneath the periosteum, on its surface; and in the case of fracture it would even appear, that a part of the lymph, which is converted into bone, is thrown out, in the first instance, by the vessels of other soft textures, exterior to the periosteum*.

The absorption of bone in the living body, is so easily produced by pressure, that bones are obviously modelled, in a great measure, by the pressure even of

* DUPUYTREN and CRUVEILHIER. See Dict. des Sciences Medicales, Art. Ossification.

soft living parts within or beneath them; and it would seem, particularly from the medullary cavities within them gradually enlarging after their growth is completed, that the presence of the medulla determines absorption to go on habitually from their interior, more than from their surface.

The red colour which is given to bones, by mixing madder with the food of animals, particularly when young, and the rapid disappearance of that colour, especially from their outer part, after the use of the madder is discontinued, are proofs of their vascularity, and of the ready escape of substances from, and subsequent re-entrance into, their bloodvessels; and of these changes taking place most readily on their outer surface. But these experiments do not prove, that the earthy matter of the bones is deposited and reabsorbed with such rapidity as the colouring matter of the madder; because the union of this with the earthy matter of the bones, and its subsequent solution in the serum, appear to be simply chemical phenomena*; and in advanced life particularly, the renewal of the bony texture, in the healthy state, seems to be a very slow process.

The Medulla, which is contained in the cavities within the bones, and confined by laminæ of the internal membrane passing across these cavities, does not materially differ from fat or other animal oils. Like the others, it has been found to consist of two oils, one fluid and the other solid at ordinary temperatures, which are mechanically separable from each

* GIBSON, Manchester Memoirs, New Series, vol. i.

other, and to which the names of Oleine and Stearine have been given. It has no connection with the synovia of the joints; nor is its use understood, except in so far as it contributes to the combination of strength and lightness in the bones, and may assist in determining their forms.

The Teeth, in the adult state, divided by their form and position into four incisores, two cuspidati, four bicuspidates, and six molares in each jaw, are distinguished from other bones by their position—being implanted in the maxillary bones, and invested only as far as the neck by periosteum—by the cavities within them, which contain a vascular pulp, and communicate with the rest of the body by the apertures at the extremities of the fangs;—and by the peculiarity of their composition, the bone which forms the greater part of each tooth containing above 70 per cent. of earthy matter, which is more than any other bones contain; and the enamel, which coats the crown of the teeth containing, according to BERZELIUS, not less than 98 per cent. of earthy matter, including above three per cent of fluato of lime.

As the bony matter of the teeth in ordinary cases, not only shews no vessels after the finest injection, but undergoes, in the adult state, no change of size or form by any vital process,—is never repaired after injury,—is unaffected by diseases of the other bones,—and appears subject to no alteration except simple decomposition,—this texture, or at least as much of it as exists in the crown of the teeth, cannot be regarded

as possessed of vitality, after the period of its growth is over ; but there may be a few cases in which strictly vital phenomena may be exhibited in it at a later period *.

II. OF CARTILAGE.

This texture is found in those parts of the body in which there is occasion for the physical qualities of strength and firmness, combined with more or less of flexibility, and with elasticity, which are its characteristic properties. From these qualities, and from its smooth surface, arise its great importance and utility in the formation of the joints, and in the junctions of various bones,—in the composition of the spine,—in the nostrils, larynx, and trachea,—external ear, &c.; but in these different situations it is found under considerable variety of density and flexibility, and, in some parts approaching to the flexibility and toughness of tendinous substance, has received the name of Fibro-cartilage. The structure of the harder cartilages, as those at the ends of bones, is almost perfectly homogeneous.

Its chemical composition appears to be nearly identical with that of the animal matter of bones. By long continued boiling in water, under pressure, it may be almost entirely converted into a gelatinous solution, but the ordinary operation of boiling leaves a considerable albuminous residue.

* See BELL on the Teeth.

Cartilage is invested with a membrane nearly resembling the periosteum, but no vessels can be traced into its substance, excepting where it is about to undergo conversion into bone. That it possesses vessels, however, may be inferred from various changes which it occasionally undergoes in the progress of life, and still more in disease; especially from its being sometimes partially absorbed, and sometimes altered in structure, without alteration of the adjoining bones.

As it contains little or no earthy matter, cartilage, in the dead body, resists decomposition much less than bone does; but, on the other hand, as it is so much less vascular than bone, it undergoes changes dependent on vital actions much more slowly, and offers much more resistance, in the living body, to the processes of progressive or ulcerative absorption.

III. OF TENDINOUS OR FIBROUS SUBSTANCE.

This substance composes not only the tendons, but the ligaments and certain membranes, viz. the Periosteum, Dura Mater, Tunica sclerotica of the eye, and Aponeuroses or Fasciæ. All these consist of delicate white fibres, of a shining or silvery appearance, differently disposed. This texture possesses more tenacity or toughness than any other in the body; and, with the exception of the periosteum and dura mater (the importance of which to the nourishment of bones was already stated), it appears to be useful in the animal economy only by this mechanical property of toughness, which renders it a sufficient attachment for the

origin of certain muscles ; the best medium of connexion by which muscles can be attached to bones, and bones to each other ; and the firmest bond by which the movements of muscles, tendons, or other parts, can be confined to the proper places and directions. That it may answer these purposes, it has, in many parts of the body, firm connexions with bones. Most parts formed of this substance resist the action of boiling water more than many other textures do ; but gelatin may be obtained from them all, and the tendons are almost entirely resolvable into it. The portion that resists the action of boiling water, does not seem to differ essentially from solid albumen.

The membranes of this class are fully provided with vessels, and give frequent evidence of alterations of the vital process of nutrition ; but the vital actions of ligaments, and more especially of tendons, are slow and feeble, and all parts formed of this texture exhibit in disease, and particularly in inflammation, less violent and rapid changes than other membranous parts. Being little liable to absorption, they often set bounds to ulceration, or other diseased actions ; and, by their physical qualities, they often compress inflamed parts, and confine, or alter the direction of, morbid effusions. Hence the practical importance of acquaintance with their anatomical disposition in the body.

IV. OF CELLULAR AND ADIPOSE SUBSTANCE.

THE first of these names is given to the soft filamentous substance very generally extended over the body, which connects together the various soft parts of the animal frame, and fills up all interstices; and the slender laminæ of which are so interwoven with each other, that when raised or distended, they appear to form numerous irregular cells communicating freely with each other. It varies much in density in the various parts, where it is interposed between the more determinate forms of other textures, *e. g.* beneath the integuments, around and between the fasciculi of muscular fibres, between membranes, around vessels, and in the substance of glands; but gives a free passage, in almost all parts, either to liquids or air. It is everywhere lubricated by a little serous fluid; and its degree of tenacity, with its softness, flexibility, and moisture, make it the best cement for holding together such parts of the body as do not require, or would be injured by, firm constraint.

This texture yields gelatin abundantly, though not readily, to boiling water. It is not only penetrated by numerous larger bloodvessels, but shews, on injection, more numerous capillary bloodvessels and absorbents, than any of those textures do in which no fluids are formed.

The quantity of serous fluid exhaled into the general cellular texture, in the healthy state, is very small. But in many parts of the body, cellular texture, of

a more determinate form, encloses within it a quantity of animal oil, and this has the name of Adipose Texture. This appears to be in a fluid or semi-fluid state, in the living body, but is retained in the cells, even in the dead body, and when rendered quite fluid by heating, until these are ruptured *.

This adipose texture is found in the greatest quantity beneath the true skin, about the kidneys, and in the mesentery and omentum, in the orbits, within certain glands about the heart, &c. There is little or none beneath the integuments of the head, in the male organs of generation, about the joints, or in the substance of most of the viscera. The composition of the animal fat has been thus stated :

Carbon.	Hydrogen.	Oxygen.
69	21.34	9.66

This, and others of the animal oils, are easily distinguished by these marks, that it melts at about 96°, is very inflammable, is insoluble in water or alcohol, and forms soap with the alkalies.

This texture is useful in those interstitial spaces in the body where a certain quantity of soft but tenacious substance is required, to obviate pressure, or preserve symmetry. The subcutaneous fat is manifestly useful in preserving the heat of the body. It is obvious likewise, from the growth of this texture usually going on long after all other healthy growth in the body is over, and sometimes, in healthy and well-fed persons, to a late period of life, that it serves as a re-

* BECLARD, Anat. Gen. p. 161.

ceptacle for superfluous nutritious matter ; but we know nothing of the principle which determines the formation of this, rather than any other animal product, in these circumstances. There is reason to think, that fat deposited in, and again absorbed from the cellular texture, is the cause of the oily appearance occasionally seen in the serum of the blood ; but it is very doubtful whether the fat that has been deposited from the blood, and again taken into the circulation, can be applied to the nourishment of any other parts.

The cellular and adipose textures are very often the seat of rapidly increased deposition from the blood-vessels, as in cases of *Anasarca*, local or general, in persons previously healthy, and in the rapid increase of bulk of persons convalescent from acute diseases, or recovering from the effects of labour and fasting. They are frequently the seat of active absorption, as is seen in the rapid disappearance of anasarcaous effusions, or of mild fluids injected into healthy cellular substance, and in the speedy wasting of the body from fasting, fatigue, or acute disease. They are also the frequent seat of inflammation and other local diseases, in the course of which both deposition and absorption are greatly increased and altered. These facts leave no room for doubt, that, in the natural state, these processes continually take place, and balance each other, in the fluid contents of these textures. The adipose texture can itself only be formed, in the healthy state, in certain parts of the system ; but the formation of a cellular substance from the blood ap-

pears to take place readily, after injuries and inflammation, in almost all parts of the body ; and even to be a general preliminary to the original formation, and to the reparation, of other textures.

V. OF SEROUS MEMBRANE.

THIS is the thin pellucid texture that lines the parietes of the great shut cavities of the body, and is reflected to form the covering of the viscera. Its free surface, towards these cavities, is perfectly smooth and moist ; its attached surface graduates insensibly into subjacent cellular membrane, from which it appears to differ only in greater condensation. It shews, in most parts of the body, no fibrous structure ; but in some parts, as the Pericardium and Tunica albuginea Testis, it approaches to the nature of fibrous membrane ; and in general, is of considerable strength, and gives a firm smooth covering to parts that are always in contact, but destined to separate movements, in which they slide on one another ; admitting likewise of much greater occasional distention than the fibrous membranes do.

In chemical composition these membranes do not appear to differ from cellular texture, but they yield gelatin sparingly and slowly to boiling water, and they resist putrefaction long. They shew hardly any blood-vessels in the living state, but very numerous capillaries and absorbents on injection ; many of which, however,

are really lodged in the cellular substance just beneath them.

Some physiologists attribute to these membranes, and even to cellular textures, a degree of the vital property of Tonicity, but its existence in them has not been clearly ascertained. Their chief vital function is the formation of the small quantity of fluid which lubricates them, and which contains the same animal and saline matters as the serum of the blood ; but the animal matter in proportions always less than in that fluid, and various in the different cavities. The proportion of albumen in the serous effusion on the pia mater, and in the ventricles of the brain, is very small.

That a continued exhalation of this fluid on the serous membranes is always going on, may be concluded from the rapidity with which increased effusion sometimes takes place in disease, or may be produced, in experiments on animals, by injecting water into the arteries* ; and that a continued absorption is going on, may be concluded from the rapid disappearance of fluid effusions there in some cases of disease ; and especially from the uniformly rapid disappearance of fluids that may be placed in contact with serous membranes in living animals, as in experiments by HUNTER, MAGENDIE, and many others.

These membranes are likewise easily increased in thickness, and altered in composition, by disease, and adventitious organized structures are often formed on

* MAGENDIE, *Precis Elementaire*.

them, by inflammation and otherwise ; but they are not nearly so liable to absorption, either from pressure, or in consequence of disease, as some other soft textures ; and these peculiarities of their vital properties are of great importance in Pathology.

The Synovial membranes, which line the inside of the capsular ligaments of joints, and are reflected in a very attenuated form over the articulating cartilages,—and similar membranes which line the sheaths of tendons, where these pass over bone or cartilage,—resemble the serous membranes in most respects, and have the same use in regard to the firm textures which play on one another in these parts, as the serous membranes have, in regard to the motions of the viscera. But they are less flexible, in the natural state less vascular, and form a more viscid fluid, containing not merely the constituents of the serum, but another animal substance which has been likened to mucilage. The alterations of their vital properties in disease are likewise less rapid than those of serous membranes ; but the changes, or even destruction, of their substance, in some instances go to a greater length.

VI. OF MUCOUS MEMBRANE.

THIS is the texture which lines all those cavities within the body which open on its external surface ; it is therefore everywhere continuous with the skin, but nowhere, except at the ends of the Fallopian tubes

in the female, continuous with any other membrane. It varies very much in thickness, and considerably in other respects, in the different parts of the air passages, alimentary canal, and organs of urine and generation ; but in all parts is distinguished by the fluid effused on it being more viscid and less translucent than serum. In most parts it is thicker, and in all parts of softer and more spongy consistence, than serous membrane, and its free surface is more completely supplied with capillary bloodvessels and absorbents, and is beset with numerous very minute prominences or *villi*. The whole membrane is in many places longer than the surface to which it is attached, and is therefore thrown into folds, increasing its surface. In most parts of the body it is studded by openings leading to minute glands and follicles, which effuse a mucus on its surface similar to that which it secretes. This kind of membrane likewise receives the outlets, and lines the interior, of the ducts of all the true glands in the interior of the body.

This texture is more acted on by cold water, and less by boiling water, than any other of the animal membranes, and is more rapidly decomposed after death than any other. The fluid found in it contains not only the animal and saline constituents of the serum, with a very small proportion of albumen, but also a quantity (according to BERZELIUS above 5 per cent.) of a peculiar animal matter, to which it owes its viscosity ; which is obtained by filtering and drying, and varies somewhat in the different mucous

membranes, but is distinguished by being easily diffused through cold water, little affected by boiling water, and not precipitated by the tests, either of albumen or gelatin, nor soluble in alcohol.

In this fluid, likewise, globules similar to those of the blood have been detected.

The surface of these membranes is the scene of continued secretion, which is obvious to the senses in various parts ; and of continued absorption, which is made manifest by the change, in quantity and quality, which is speedily effected in any substances placed in contact with them. There is also, in the healthy state, very great occasional variation in the quantity of blood sent to them, and in the quantity of secretion formed on them ; and, in the case of the stomach particularly, in the quality of that secretion. The causes and purposes of these variations will be considered afterwards.

The characteristic qualities, and especially the vital properties, of all the mucous membranes, appear to be immediately connected with the circumstance of their forming the surface over which all foreign substances taken into the body, and formations in the body destined to excretion, must necessarily pass. By these, the vital actions of secretion and absorption going on in them are continually stimulated ; and such is the adaptation of their vitality to the action thus exerted on them, that the same substances which only excite them to healthy and salutary action, no sooner touch the surface of serous or synovial mem-

branes, or even of cellular texture, than they excite violent inflammation.

The activity of the vital actions that take place in these membranes, is farther attested by the frequency of increase and alteration, both of their secretion and of their nutrition in disease, and by the peculiar liability of those of the alimentary canal, at least, to ulcerative absorption.

VII. OF GLANDS AND THEIR SECRETIONS.

CONFINING the term Gland to those organs of the body which separate peculiar fluids from the blood and discharge them by ducts, we find much variety as to the disposition of these ducts or their branches.

The simplest kind of gland is a short membranous canal, opening on the surface of a mucous membrane, or of the skin,—such as the lacunæ of the urethra, and the Sebaceous, Meibomian, and Ceruminous glands or follicles. Even by so simple an apparatus, very various substances are formed.

Most of the glands that pour out mucus on the mucous membranes, consist of a pulpy vascular substance surrounding a little canal, and these are often set together in clusters, as in the Tonsils, glands of PEYER and BRUNNER, &c.

In all the larger glands, the excretory duct is formed by the union of smaller tubes within the substance ; but in the arrangement of these smaller tubes

there is much variety. The smallest divisions of the glands, which have the secreting power, or the *acini*, seem to be similar in structure to the mucous glands just mentioned. In the strictly conglomerate glands, as the Salivary glands and Pancreas, these acini are connected into lobules, and the lobules into lobes, by distinct layers of loose cellular substance; and each lobule has its own duct passing along its central part. In the Liver and Kidneys, there is no such internal division into lobules, the acini being connected uniformly with each other, by dense interstitial cellular texture throughout the secreting parts of these glands. A large portion of the substance of the kidneys consists of the excretory tubes exclusively, set close together, and converging very gradually to the papillæ, which pour the urine into the calices. The excretory ducts of the Mammæ are so coiled up in the substance of the nipples, as to require the erection or extension of these, before they give free exit to the milk. The seminiferous tubes, which terminate in the vasa deferentia, are distinguished by their very numerous contortions, first in the body of the Testis, and afterwards in the epididymis.

All the excretory ducts have probably a certain amount of vital contractile power, though muscular fibres have been detected only in a few. In several cases, the fluids secreted are retained for a time in peculiar organs, before they are applied to the purpose to which they are ultimately destined. The tears, formed in the lachrymal gland, are effused over the eye-ball, and absorbed into the lachrymal sac, be-

fore passing into the nostrils ; the urine is lodged in the bladder long after its secretion is accomplished ; the bile regurgitates in part into the gall-bladder ; and perhaps the semen into the vesiculæ seminales.

All the glands are very fully furnished with blood-vessels and with absorbents ; their arteries are stated to be of peculiar strength *, and are very minutely subdivided in their substance.

The supply of blood to all the glands, as to the mucous membranes, is also liable, in the healthy state, to great and sudden variations, from different causes, mental and physical. These are attended by great differences in the amount of the secretions formed there ; and there is also great variety in the quantity and quality of the secretions in various diseased states. The nutrition of the glandular substance itself is, in some instances, subject to change in the progress of life, and in general is easily increased or perverted in disease. Absorption of the secreted matters takes place readily from the whole course of their outlets, as is obvious when the excretions of bile, urine, or milk, are unusually long retained, or their excretion obstructed ; and absorption of the substance of glands themselves is easily effected, apparently by pressure, in those cases where their ducts are long obstructed, or where preternatural deposits take place in their neighbourhood, or in their own interstitial cellular substance.

The most important distinction of the secreted fluids, as regards physiology, is into the *recrementi-*

* WINTRINGHAM.

tious and *excrementitious* ; *i. e.* into those which are destined to some ulterior purpose in the animal economy, and those which are immediately excreted.

To the former class, besides the mucus of the mucous membranes and glands, have been referred the tears, which moisten the tunica conjunctiva of the eyeball and membrane of the nostrils ; the cerumen, which is found in the meatus auditorius externus ; the saliva, coming from the parotid, submaxillary, and sublingual glands, which is mixed with the food in the mouth ; the secretion of the stomach, which is the chief agent in digestion ; the pancreatic fluid and bile, which descend from the liver and pancreas, to be mixed with the aliment in the duodenum ; and likewise the semen, and the fluid of the prostate gland, which is mixed with it at the origin of the urethra. These are stated by BERZELIUS to contain always the same saline ingredients as the serum of the blood, but little or no albumen,—and, instead of it, a single animal substance, varying of course in each instance : but subsequent observations do not entitle us to attribute so great simplicity to all these fluids. These secretions are generally, like the serum, slightly alkaline ; but to this there is a remarkable exception in the secretion of the stomach, to be afterwards considered ; and likewise, according to TIEDEMANN and GMELIN, in the secretion of the pancreas. The chemical qualities and composition of the animal matters which they respectively contain, have been but imperfectly investigated, and cannot, as yet, be connected with their uses.

The most peculiar is that which is contained in the Bile, forms nearly 8 per cent. of it, and causes its bitter taste, and is most simply obtained from it, first by sulphuric acid, which precipitates it, and afterwards by baryta, which separates the acid. This has been likened to the vegetable resins, and stated to contain a small proportion only of hydrogen, and no azote; its analysis being, according to THOMSON,

Carbon.	Oxygen.	Hydrogen.
54.53	43.65	1.82.

But whether there is in reality only a single animal principle in this fluid, or whether the picromel, cholesterine, and other substances which have been obtained from it by different processes, or separate spontaneously from it in biliary calculi, exist in it at all times, is doubtful.

In regard to the bile, there are two important physiological questions which may be stated here; 1st, Whether it is simply destined to excretion, or necessarily employed in digestion? 2d, Whether it is formed from the arterial or the venous blood of the liver?

1. It appears from various facts, that the peculiar animal matter at least of the bile, is destined to excretion only. This matter has never been found, in the healthy state, in the fluids absorbed from the intestines by the lacteals or veins; it is found in full quantity in the lower part of the intestines; it has been found to increase in quantity where the secretion of urine has been suppressed in animals by extirpa-

tion of the kidneys; and, where this secretion is repressed, the urine is increased and altered *; and it appears to be similar to a secretion in certain animals (of the class Mollusca), which is thrown out into the lower part of the intestine only, and immediately excreted †. The use of the other constituents of the bile, in digestion, will be considered afterwards.

2. Instances have undoubtedly happened in the human species, where the vena portæ had not entered the liver, and bile been nevertheless secreted. But, on the other hand, the experiments of MALPIGHI and of SIMON, shew that tying the hepatic arteries in different warm-blooded animals, had little effect on the secretion of bile, but that it was suppressed by tying the vena portæ. The only other instance known of venous blood going to a gland, is the case of those animals where large veins enter and are dispersed through the kidneys, and where any thing that escapes from them must be immediately excreted ‡.

The most reasonable conclusion from these facts seems to be, that the liver can form bile both from arterial and venous blood; but that the latter is its chief source.

The formation of the Milk, secreted at the mam-mæ, is dependent on conditions to be afterwards stated. It is one of the fluids destined to excretion

* PREVOST and DUMAS, in the *Annales de Chimie*, t. xxiii. and SIMON, in the *Annales des Sciences Naturelles*, t. xiii. p. 110.

† TIEDEMANN and GMELIN, *Recherches sur la Digestion*.

‡ JACOBSON, *Edin. Med. and Surg. Journ.* vol. xix.

only, and which cannot be retained in the system without more or less of injury; and demands attention on account of its analogy to the composition of the blood on the one hand, and to the materials of digestion on the other.

Its specific gravity is about 1033, greater than that of the serum, but considerably less than that of the blood. Its basis is water, holding in solution several salts, chiefly salts of potash, with an excess of lactic acid; but it contains also three animal matters, first, the Butter, which separates spontaneously, or by agitation, and does not differ materially from other fixed oils; *secondly*, the Curd, or Caseous Matter, stated at 28 parts in 1000 in cow's milk, which separates spontaneously, but very slowly, and is precipitated most easily by acids,—closely resembling albumen, but not so easily coagulated by heat; and *thirdly*, the Sugar of Milk, stated at 35 parts in 1000, which remains in the whey after the separation of the curd, and is obtained by evaporation and crystallization, and hardly differs in composition from vegetable sugar. Of these three, the curd only, containing Azote, is similar to most articles of nourishment from the animal kingdom; the oil and the sugar are analogous to the greater part of vegetable nourishment. The curd yields, when burnt, about 6 per cent. of earthy phosphates, and is, therefore, supposed to be useful in the formation and nourishment of bone.

The proportion of curd appears to be less, and its mixture with the oil more intimate in human milk than in cow's milk; and in all animals, the proportion

of curd is less in the milk formed soon after parturition, than in that formed subsequently.

The most important excretion formed in glands is the Urine, which passes along a mucous membrane in its way from the kidneys, and is lodged for some time in the bladder, and is therefore mixed with a small proportion of mucus when passed ; which mucus is somewhat heavier than the urine itself.

Urine has an average specific gravity of about 1025; 933 parts in 1000 of it are stated to be water ; above 30 are the peculiar animal matter called Urea ; and the remainder consists of salts in greater proportion and greater variety, than in any other fluid of the body, with a little of another animal matter, probably similar to that in the serosity of the blood. The salts generally allowed to exist in it are, the Sulphates of Potass and Soda, Phosphates and Murates of Soda and Ammonia, Phosphates of Lime and Magnesia, Lactic Acid, and Lithic Acid, or Super-Lithate of Ammonia. Minute quantities of Fluete of Lime and of Silica have been recognized in it ; and Carbonic Acid has been obtained from it by the air-pump only. Of these, the acids are in excess, and hence the Lithic, being a weak acid, is frequently deposited, and is apt to attach itself to and lead to decomposition of the mucus. But in other circumstances of the urine, and particularly, when there is not the usual excess of acid, the phosphates are most easily deposited from it ; and the Oxalic Acid, and other substances not detected in healthy urine, have been frequently found in gravelly deposits.

The Urea is dissolved from the Extract of Urine, by alcohol, and obtained by evaporation, partly separated from the saline matters; it has a peculiar taste and smell, and is characterized by the bulky flaky compound it forms with nitric acid. By putrefaction, or by the heat of boiling water, as it exists in the urine, it is almost entirely converted into carbonate of ammonia; and it has been found to consist of

	Carbon.	Oxygen.	Hydrogen.	Azote.
	19.99	26.66	6.66	46.66
or	1	1	2	1 atoms.

containing therefore a much larger proportion of azote than any other animal principle.

The average quantity of urine evacuated in 24 hours may be about 40 ounces; but is liable to very great variations. The average quantity of solid matter that passes off by this excretion has been found to be not less than 15 drams in 24 hours*; and is apparently much less subject to variation, excepting in disease; the density of the urine, in the healthy state, being always diminished as its quantity is increased, and *vice versâ*.

The appearance, already noticed, of urea in the blood, when the kidneys have been extirpated, or obstructed by disease, shews that the formation of this substance is at least so far advanced, before the blood,

* Dr BOSTOCK (Medico-Chirnr. Trans. vol. iii.) makes the quantity only 10 drams, but the experiments of Dr HENRY (ditto, vol. ii.) shew, that, even at the specific gravity of 1020, a pint of urine yields above 6 drams of solid extract, and therefore 40 ounces must yield above 15.

from which it is separated, enters the kidneys. And the conjecture of BERZELIUS, that it is furnished by the animal matter of the serosity of the blood, is rendered probable by two circumstances,—*first*, that the qualities of that portion of the blood (particularly its solubility both in water and alcohol) approach nearer to those of the urea than the qualities of the albuminous contents of the blood do; and *secondly*, that after the extirpation of the kidneys, the animal matter of the serosity is first increased in quantity, and afterwards assumes the character of urea*.

It has also been supposed that the animal matter of the serosity, thus apparently convertible, at least in part, into urea, is not intended for nutrition, but is the product of that absorption from the component parts of the animal frame, which we saw reason to believe to be a necessary accompaniment of all vital action, and is destined to excretion only. And this opinion is farther supported by the phenomena of Diabetes, where there is ample evidence of very general absorption, from the wasting and dryness of the body, notwithstanding that more than the usual quantity of nourishment and drink are taken,—and in which the animal matter of the urine is enormously increased; and appears, from the observations of Drs BOSTOCK and HENRY†, to retain, at least in some cases, the properties of urea for a time, and afterwards to assume, for the most part, the character of sugar; which conversion is probably in some way connected

* PREVOST and DUMAS, *Annales de Chimie*, t. xxiii.

† *Medico-Chirurgical Transactions*, vol. iii.

with the chemical relation, discovered by Dr PROUT, between urea and sugar, viz., that the latter contains the same number of atoms of carbon and of oxygen as the former, with half as many atoms of hydrogen, and no azote*.

Whatever be the source of the urea, which is separated from the blood at the kidneys, the necessity of this excretion appears distinctly from the fact, that when the blood is unusually loaded with this principle, it gradually acts as a poison on the system, and especially on the Nervous System; as has appeared uniformly when the kidneys of animals have been extirpated; and also, although in a less uniform manner, in the human body, when the secretion of urine has been either wholly suppressed, or more gradually and partially obstructed.

The facts now stated are already important in Pathology and in Practice; but the Physiology of Excretion, as well as of Secretion, will always be obscure and unsatisfactory, until we shall have some information as to the laws according to which chemical principles are modified in the economy of animals.

VIII. OF THE SUBSTANCE OF THE LUNGS.

ALTHOUGH the mutual action that takes place between the air and the blood at the lungs, the manner in which it is effected, and its uses in the animal

* Medico-Chirurgical Transactions, vol. viii.

economy, demand a separate consideration, yet some statements, as to the texture of the lungs, and the nature and amount of the excretions from them, are more properly introduced here.

This texture, although varying much in density in different subjects in consequence of the different quantities of blood it contains, is always, in the healthy state, of less specific gravity than water, because, from the time of birth, it always contains within it a large quantity of air, which is lodged in innumerable small cavities or air-cells, formed by little expansions of the ends of the ramifications of the bronchiæ which enter it. The texture may be said to be composed of mucous membrane, cellular substance, and serous membrane, with very numerous bloodvessels and absorbents. The membrane forming the cells, and on which the innumerable branches of the pulmonary artery and veins ramify, is continuous with that which lines the larger, and partly cartilaginous, branches of the bronchiæ, that enter the lungs from the trachea; and, although of extreme tenuity, is believed to secrete a mucous fluid. The air-cells are bound together, and covered exteriorly by cellular substance, the cells of which, in the natural state, do not communicate with the bronchiæ. It is probable, though not completely ascertained, that the air-cells in the natural state do not communicate with each other, otherwise than by the branches of the bronchiæ, which open into them. The exterior cellular substance is bounded by the Pleura Pulmonalis, which is everywhere in contact with, but in the natural state nowhere adherent to,

the serous membrane that lines the inside of the parietes of the chest. The compound texture thus formed is endowed with a high degree of distensibility and elasticity, which are its most important physical qualities.

It is generally thought that this texture possesses no vital power of contraction ; but several phenomena to be afterwards mentioned, render it probable that such a vital power does exist, to a certain degree, in it ; or at least in the smallest branches of the bronchiæ that can be distinguished.

Air which has been in the cells of the lungs during life, is always found to be loaded, in an unusual degree, with water and carbonic acid, much of which is evidently derived from the air-cells ; and the mode of their formation will be considered under the head of Respiration. From some experiments by Dr GORDON, it would appear that no saline or animal matter can be detected in air that has been breathed, the water and carbonic acid being the only excretions, or exhalations, from the membrane of the cells.

That absorption goes on with great facility and rapidity from the internal surface of the lungs may be concluded from experiments, already mentioned, in which saline solutions, introduced into the bronchiæ, have been very soon thereafter detected in the blood, and likewise from the certainty and rapidity with which vapours, such as those of mercury or oil of turpentine, introduced into the lungs, come to produce the usual effects of those substances on the secretions. The effects of poisons introduced into the lungs, al-

though rapid and decided, are not so clear proofs of absorption.

The average loss of weight in a full grown man, in the day, which can be ascribed to the excretion at the lungs, appears, from experiments to be mentioned afterwards, to be not less than fifteen ounces; and the facts now stated prove, that this must be only the excess of the excretion over the absorption at the lungs.

The black colour of portions of the lungs, and of the bronchial lymphatic glands connected with these, has been ascribed with some probability to absorption of carbonaceous powder from the internal membrane.

The changes which take place in the form and size of a healthy lung from the pressure of adjoining parts, and the expansion of one lung observed in cases where the other has been rendered unfit for its office, are sufficient proofs of the facility with which both absorption and nutrition of the pulmonary texture itself may be accomplished. The latter function is probably performed by the bronchial arteries only. There is good evidence, from the phenomena of different diseases, that the function of absorption in this texture is adequate, when other circumstances are favourable, to the removal, at least of serum and of blood, and perhaps of other matters morbidly effused into it.

IX. OF THE SKIN.

THIS is commonly described as consisting of three layers; the True Skin which lies innermost, the Cuticle which is external, and the Rete Mucosum which connects these; but this last is not easily distinguished, except in blacks, in whom it is the seat of the colour. Both it and the cuticle are extravascular and inorganic.

The *true skin* is a firm dense membrane, of a fibrous and reticulated texture, extremely elastic, at least in youth and middle age, marked with varied lines externally, and with very numerous depressions internally, which receive processes of the adipose texture beneath; very fully supplied both with minute blood-vessels and absorbents; containing, in many places, the sebaceous glands or follicles, and perforated obliquely in many others by the hairs, which spring from little bulbs beneath it. It is almost entirely resolvable into gelatin, but requires long-continued boiling for this purpose.

A degree of vital contraction would appear to take place in this texture occasionally, particularly from the influence of cold, and of certain mental emotions.

The facts mentioned at p. 86, shew that the change of this texture by nutrition and absorption, in ordinary circumstances, must be very slow; but in different diseases, it is obvious that these vital actions in it take place rapidly and extensively.

The surface of this membrane is certainly the scene

of three vital processes ; the formation of the Cuticle, Perspiration, and Absorption.

The Cuticle is easily detached from the true skin, by the action of a blister, in the living body, and by putrefaction in the dead. It is a thin, very elastic membrane, composed almost entirely of solid albumen. Its formation is no doubt continual, as it is obviously subject to continual waste from friction, and is much increased or excited by irritation or pressure, as in the palms of the hands or soles of the feet. Although an inconsiderable texture in the human body, when compared with the corresponding parts of many other animals, it is of great importance in the animal economy, particularly by restraining the amount of the vital actions which take place on the surface of the true skin. For this purpose it is especially fitted by the cohesion of its parts, which is such as to transmit any fluid substance very slowly, as appears in the dryness of its surface when it is raised in a blister ; and again in the rapid drying of the surface of the true skin whenever the cuticle is removed from it in the dead body.

The Nails consist of the same material as cuticle, with very little earthy matter, but of much firmer consistence, and more firmly attached to the true skin beneath them, than any other parts of it, and are remarkable for the mode of their growth ; their outer layer seems to be formed entirely in the folds of skin at their roots, and pushed forward by continued accretion there, while other layers are added to their inner surface by the portions of skin over which they pass.

Although the Hair is usually regarded as equally inorganic with the cuticle and nails, yet there are some facts which appear well ascertained, particularly sudden changes of the colour of the hair, from mental emotion, or other causes, which seem to indicate that vital processes of nutrition and absorption go on in this substance itself, although its growth seems to be confined to the bulb beneath the cutis vera.

The colour of the hair depends on exposure to the light, and is no doubt connected either with the formation, or with some alteration, of an oil which is found in their texture. Hair is partially resolvable by boiling in water under pressure, although with different degrees of facility, into a gelatinous matter; but part is decomposed by this process, and gives distinct evidence of containing sulphur.

The vital processes by which the cuticle, hair, and nails are constantly formed, are liable to alteration from heat and cold, and other causes; and especially by those diseases in which inflammation of the skin takes place. The hair drops off sooner, or is sooner changed in colour, in those persons and circumstances; where there is much sweating. The shedding of the hair is a common effect of long-continued febrile action, even independently of cutaneous inflammation; and the separation and renovation of the cuticle, after the specific inflammations of the skin have run their courses, appear to be essentially connected with the recovery of health.

The passage of fluids outwards through the cuticle, appears to take place more easily when it retains its

connexion with the true skin, through the rete mucosum, than when it is detached by a blister; and is determined by various causes; by external heat, exercise, and other means of exciting the circulation; by mental emotion; and also remarkably by failure of the heart's action, as in fainting. In this last case, it coincides with the appearance of an unusual proportion of serum in the blood of the large veins*; and both are probably to be ascribed to a tonic constriction of the smaller bloodvessels, no longer distended, as previously, by the impulse from the heart. -

The sensible perspiration, or Sweat, appears to contain an excess of lactic acid, a small quantity of the same alkaline and earthy salts, and the same uncoagulable animal matter as the serum, and also of an oil, probably in part, but not wholly, formed in the sebaceous glands. The quantity of these substances seems to be much less variable in the healthy state, than that of the water which passes off from the skin; because the sweat, like the urine, becomes much attenuated when its quantity is increased.

Even when no fluid is visible on the surface of the skin, a quantity of watery vapour is always exhaled from it, as appears when the hand and arm are confined in a glass jar. The air in immediate contact with the skin has also appeared, in many experiments, as those of CRUICKSHANKS, JURINE, and some of those of Mr ELLIS and Dr C. MACKENZIE, to contain an unusual proportion of carbonic acid; but the formation of this acid could not be recognized at all

* DAVY, De Sanguine.

in some experiments, such as those of Dr KLAPP and Dr GORDON ; and in all cases, appears to be so small, that this excretion cannot be regarded as an important part of the functions of the skin. Its very small quantity has prevented physiologists from ascertaining whether it is essential to the appearance of this acid, that the skin should be in contact with a gas containing oxygen ; but, in some experiments by SPALLANZANI and by Mr ABERNETHY, this condition did not appear necessary.

The average quantity of exhalation from the human body by the skin and lungs together, *i. e.* the whole loss of weight from these sources, taken together, is stated by HALLER, on comparison of the results of many observations, to vary from 30 ounces in the 24 hours in the colder climates, to 60 in the warmer, of Europe ; and by LAVOISIER and SEGUIN it is stated at 45 ounces in the climate of Paris ; but is liable to very great variation, not only according to the temperature and humidity of the atmosphere, but also according to the diet and habits of individual persons, and the state of repletion of their vessels.

Of this exhalation, it appears from the experiments of LAVOISIER and SEGUIN, that about 2-3ds or 30 ounces are from the surface of the skin, and 1-3d or 15 ounces from the lungs.

The amount of loss sustained by the exhalation from the lungs has been already stated as in reality only the excess of the exhalation over the absorption habitually taking place there ; but it is more doubtful whether any compensating absorption habitually takes place at the skin.

Many familiar facts illustrate the great absorbing power of the vessels of the true skin, over such matters as are either mechanically forced through the cuticle, or introduced where it has been abraded; but the possibility of absorption through the entire cuticle is much more doubtful.

Various observations made by RYE, LINNING, FONTANA, and others prove, that, in certain circumstances, and especially during fasting, when absorption is unusually active, not only the usual waste of the body by exhalation from the skin and lungs may be suspended, but an absolute increase of weight may take place during a time when no food or drink has been taken, only to be explained by absorption at the skin or lungs; and observations on the comparative amount of the ingesta and egesta, and on the loss of weight, of patients in diabetes, have also led to the conclusion, that there must be an excess of absorption over exhalation at these surfaces*. But these observations do not prove that any part of the absorption in question is at the skin.

Of the many observations made by the warm-bath to ascertain this point, the general result may be stated thus;—That the rate of waste of the body, previously existing, has been generally lowered, sometimes the waste altogether stopped, and, in a few cases, an absolute increase of weight to a small amount, has resulted from immersion for half an hour or more; and this where there was at least probable evidence that

* See DILL on Absorption by the Skin, Edinburgh Medico-Chirurgical Transactions, vol. ii.

the absorption of the lungs had not increased *. These experiments shew that a certain quantity of fluid may be at least imbibed by the cuticle, and probably absorbed from it.

But in the experiments of SEGUIN, ROUSSEAU, DANGERFIELD, and GORDON, made chiefly by applying liquids to the surface of the body, which have a known effect, when taken into the blood, on certain secretions (care being taken that the vapours of these should not be inhaled), no evidence of absorption from the skin, when the cuticle was entire, could be procured; and the different result of two experiments made in the same way by Dr YOUNG, is not enough to set aside the conclusion, that the amount of absorption in the human body, through the entire cuticle, where no pressure is used, is in general trifling; particularly when compared with the activity of absorption at the lungs.

The whole amount of watery excretion from the skin and lungs manifestly alternates, in the healthy state, with that by the kidneys; the effect both of external heat, and of exercise, which increase the former, being to diminish the latter. But the quantity of the secretion of bile, and probably also of mucus in the intestines, though apparently diminished by violent excitation of the circulation, as by hard exercise, does not alternate with the amount of the exhalation at the skin and lungs; being usually increased, simultaneously with these exhalations, both by moderate exercise and by warm seasons or climates.

* See particularly Dr DILL's paper, and Dr YOUNG's Thesis, Edin. 1817.

X. OF MUSCULAR TEXTURE.

THE external aspect and vital properties of this texture, the chief seat of vital contractions, have been stated already ; and its distribution over the body, and the purposes to which it is applied, appear in the account of the different functions in which it is employed ; but some facts may be stated here, chiefly in relation to its chemical composition, and its nutrition and absorption.

Although the smallest muscular fibres appear every where similarly constituted, there is much variety as to their arrangement and connexions in different parts of the body. Those which are destined only to involuntary motion are generally attached to soft parts ; their course is more complex ; they are generally of looser texture, and more distensible, than those of voluntary muscles ; but their vital contractions appear at least as forcible. Those destined to voluntary motion are generally of denser texture, and redder colour ; they are, for the most part, attached to bones and fibrous parts, and are divided, by the disposition of their fibres, into straight, radiated, penniform, compound penniform, &c.

By boiling water on muscles, a quantity of albumen, which takes the solid form ; of gelatin, which becomes solid on cooling ; and of extractive matter or osmazome, which remains in solution ; and several salts, are obtained from them ; and the fibrin that re-

mains still preserves the original form, though, when perfectly dried, stated not to exceed 17 per cent. of the whole weight. The Osmazome is the principle which gives taste and smell to muscular flesh; it is the most putrescible part of the substance, and is distinguished by its solubility both in water and alcohol; nearly resembling, in this and other respects, the uncoagulable matter of the serosity of the blood.

The subdivision of bloodvessels in the substance of muscles is not so minute as in those textures where fluids are secreted, and their nutrition and absorption are slow. They are often seen gradually to acquire great increase of bulk, particularly in consequence of frequent excitation; and to waste from inaction, from disease, and from the effects of certain poisons. But their substance is not easily, if at all repaired, by similar texture, after laceration or rupture; and they are very little liable to any such alterations in disease as imply rapid deposition and absorption.

It may be stated here, in general terms, that muscles are useful in the animal economy, by vital contractions, directed to one or other of the three following ends. *First*, To diminish a cavity which they surround, as in the case of the heart, stomach and intestines, bladder, &c. *Secondly*, When both of their extremities are fixed, or nearly fixed, to alter their own direction, and thereby expand or compress adjoining parts, as in the case of the diaphragm, buccinator muscle, &c. *Thirdly*, Where one of their extremities is fixed, and the other moveable, to draw the lat-

ter towards the former, as in the case of almost all the strictly voluntary muscles of the trunk and extremities.

XI. OF NERVOUS SUBSTANCE.

IT is necessary here, in the first place, to recollect the different parts of which the Nervous System, in man, and other vertebrated animals, consists; the Brain, Cerebellum, Medulla Oblongata, and parts connecting these, enclosed within the cranium; the Spinal Cord, situate in the canal of the vertebræ; and the Nerves, originating from these, and extending, by innumerable ramifications, probably to all parts of the body in which vessels can be traced: next, the protection given to the larger masses of the nervous system by the bones of the head and spine, and by the three membranes which envelope them within these bones; and to the nerves, by their concealed situation in most parts of the body, and by the firm membrane investing them; and lastly, the division of the nervous matter into grey or Cineritious, and white or Medullary, and the general disposition of these; the grey matter covering the white in the convolutions of the brain and cerebellum, lying within it in the spinal cord, and alternating with it, in different forms, in the tuber annulare, and in various of the central parts of the brain.

The outer surface of the serous membrane which immediately invests the brain and spinal cord, is al-

ways moistened by an attenuated serous fluid, which is confined beneath the arachnoid on their exterior, and contained within the ventricles in the interior of the brain ; and these two portions of the fluid, in the natural state, appear to communicate by the small opening at the extremity of the fourth ventricle.

As membranes continuous with the pia mater descend between the convolutions, and into the cavities or fissures of the brain, no part of the nervous matter there is distant from the vascular membrane, from which it derives its blood, and on which the vessels ramify minutely before they penetrate it ; and the same holds of the nerves, all of which are composed of great numbers of very slender filaments, bound together by cellular substance, which receives minute vessels from the neurilema.

The nervous matter, both grey and white, appears, under the microscope, to be composed, in a great measure, of minute globules ; and these, in the medullary substance, are arranged into fibres, which are in few places distinctly perceptible in the recent state, but become obvious after hardening by alcohol, boiling oil, diluted nitric acid, &c.

The following general facts, in regard to the anatomical distribution of the nervous system, appear to be those which most immediately connect themselves with its physiology.

1. The nerves may be divided, as was pointed out by Mr BELL, into Symmetrical and Irregular ; the distinctions of which are, that the former arise from the larger masses of the nervous system, by double roots,

an anterior and a posterior ; that there is a ganglion on the posterior, where it passes through the dura mater ; that they pass out, in general, nearly at right angles to the surface from which they arise, and do not cross each other, nor inosculate till they are at some distance from that surface ; and that they form a complete system, supplying all parts of the body, whether these have other nerves or not ; whereas the irregular nerves have no such regular arrangement of double roots, pass out in more various directions, several of them cross, and some inosculate freely with the other class of nerves, and so unite the different divisions of the frame ; and they always go to parts which have likewise nerves of the symmetrical class.

The first class comprehends all the pairs of the spinal nerves, thirty in number, and the fifth pair of the cerebral. There is more difficulty as to the arrangement of the cerebral nerves ; but physiological facts, to be afterwards stated, seem clearly to indicate that those cerebral nerves which go to muscles only, the third, probably the fourth, the sixth, portio dura of the seventh, and ninth, as well as the smaller or anterior branch of the fifth, correspond to the anterior portions of the spinal nerves, and are to be ranked in the symmetrical system. The nerves strictly belonging to the irregular class, are the eighth pair, the spinal accessory nerves, the phrenic, and external respiratory nerves of Mr BELL, and the great sympathetics. The first, second, and portio mollis of the seventh, the functions of which are well known, may

be either ranked as irregular nerves, or be separated from both classes.

2. Some of the nerves pass to the organs to which they are destined, and are subdivided there, without inosculating with any others on the way; but by far the greater number of the nerves are connected with others, either by Plexuses or Ganglia. The former are multiplied unions and separations of the larger branches of nerves, without any intervening substance; and the most striking instance is the axillary plexus, formed by the nerves of the symmetrical system, going to the arm; but a similar intermixture of filaments no doubt takes place in the sciatic and crural nerves, which are formed by the lumbar and sacral nerves; and the irregular nerves of the trunk of the body are very generally connected in this way. The ganglia are oval or roundish bodies, formed in part of a vascular pulpy substance, within which there is a separation and reunion of nervous filaments entering them, as close and intimate as that of the absorbent vessels within a lymphatic gland. These are found on the posterior roots of the symmetrical nerves; but the greater number, and most characteristic examples, of the ganglia, are found on the great sympathetic nerve, the course of which is parallel to the spinal column,—at the points where it crosses and communicates with the symmetrical nerves that pass out from the spinal cord. Many internal parts have their nerves exclusively from these ganglia; and these are thereby connected with the whole extent of the spinal

cord, and hardly with any individual point of it more than with another.

3. All the nerves, symmetrical and irregular, have their origin either from the Spinal Cord itself, or from parts at the base of the brain, not higher than the tubercula quadrigemina and crura cerebri, which are easily shown to be its prolongations; *i. e.* they arise from what has been called the *Cerebro-Spinal Axis*, on which the brain and cerebellum are superimposed.

4. The Spinal Cord is obviously divided into two similar portions by its anterior and posterior median fissures; and each of these halves of the cord is again, though less obviously, divided into an anterior, middle, and posterior column. The anterior and posterior roots of the spinal nerves come off just where the anterior and the posterior join with the middle column; and the small quantity of grey matter within the cord projects towards the same points. The anterior columns appear to lead up to the corpora pyramidalia, the middle to the corpora olivaria, and the posterior to the corpora restiformia. The course of the chief fibres of all the columns of the spinal cord, as traced after hardening the nervous matter, is longitudinal and uniform, as high as the medulla oblongata; but at the lower part of the corpora pyramidalia, the course of the fibres, especially of the anterior and middle columns, becomes more complex, and is traced with difficulty; and a partial decussation of the fibres, below and behind the corpora pyramidalia, is observed. But it is obvious, that the greater part of the medullary fibres from the spinal cord, and especially those

from its anterior and middle columns, pass forward, through and behind the tuber annulare, to form the *crura cerebri*; and also that another portion of them, chiefly from the posterior columns, pass through the *corpora restiformia* into the cerebellum.

5. The Brain proper, may be considered as composed of a central nucleus, and of folded laminae or convolutions set around it at right angles to its surface. The convolutions consist of plates of medullary substance, with coverings of cineritious matter, not strictly continuous with any of the fibres composing these plates.

From the descriptions of those who have examined the fibrous structure of the brain the most accurately, and particularly of REIL., it would appear that the central nucleus consists of two sets of medullary fibres, one of which has been called Vertical, the other Horizontal, from their most general directions, though both are much convoluted in some parts of their course. These intersect one another variously in different parts of the brain, and have portions of grey matter, of various size and figure, interposed among them.

The vertical fibres are continuous with those that ascend from the spinal cord, through the *crura cerebri*, after crossing the tuber annulare. They pass up on the outer side of the *thalami nervorum optico-rum*, and radiate thence, in all directions, to the bottom of the convolutions; many of them, on each side, passing obliquely through the *corpus striatum*, in a broad band (the inner wall of the capsule of

REIL), which divides it into two parts ; and some of them terminating in the grey matter of the corpus striatum. The thalami and corpora striata, as well as the corpora quadrigemina, are appendages to this vertical portion of the fibres. It is probable, though not distinctly demonstrable, that these vertical fibres are continuous with, and terminate in, the plates that form the central medullary portion of the convolutions.

The horizontal fibres are confined to the brain, not descending to the spinal cord : the principal parts which they constitute, in the central parts of the nucleus are, the corpus callosum, and the different commissures, where they run transversely ; and the fornix, and its crura, where they run longitudinally. Towards the exterior of the nucleus, there are found not only the prolongations of the transverse horizontal fibres, but also other fibrous bands, which are wrapped around the base of the convolutions, and connect these with each other *.

6. The lobes and lobules of the cerebellum consist, like the convolutions of the brain, of medullary fibres arranged into laminæ or plates, which are set around an irregular nucleus. In that nucleus, there are transverse or horizontal medullary fibres uniting the

* See REIL's Papers, translated by MAYO, in his *Anatomical and Physiological Commentaries*. GORDON on the Structure of the Brain. Report of a Committee of the French Institute on GALL and SPURZHEIM's Anatomy of the Brain, in *Edinburgh Medical and Surgical Journal*, vol. v.; and Report by CUVIER on FLOURENS's Experiments on the Nervous System, in *Journal de Physiologie*, t. ii.

laminae at their base; but the greater part of the central nucleus of the cerebellum consists of fibres continuous with the medullary plates of the lobules, which pass forward to connect themselves with the cerebro-spinal axis by three columns; *first*, By the corpora restiformia, which connect themselves with the posterior columns of the spinal cord; *secondly*, By the crura cerebelli, which form the tuber annulare, by crossing and encompassing the larger portion of the spinal cord on its way to the crura cerebri; *thirdly*, By the valve of Vieussens, and its pillars (originating partly in the corpus dentatum, within the medullary portion of the cerebellum), which connect themselves with the crura cerebri, below the corpora quadrigemina.

The Ventricles or Central Fissures of the Brain and Cerebellum, may be said to result from the separation of the vertical portions of the two hemispheres from one another, and from the apposition of the horizontal portions over them.

The apparent implantation of the vertical fibres of the brain and cerebellum on the grey matter of the convolutions and lobules, and on that of the corpora striata—the origin of some of the fibres of the crura cerebri in the corpus dentatum,—and the extension of the grey matter of the spinal cord towards the origins of most of the nerves,—have led to the opinion, that it is essential to the functions of medullary fibres that they should terminate, by one extremity, in cineritious substance. But strong objections to this opinion have been stated by MAGENDIE and DESMOULINS, particularly, that in many fishes and reptiles cineri-

tious matter exists in the brain, but not in the spinal cord, yet the nerves arising from the spinal cord are fully adequate to their functions ; and again, that the functions of the spinal cord, in regard to sense and motion, appear, from experiments to be afterwards stated, to reside in its surface chiefly, and not in its interior, but the grey matter is found in the interior only.

The nervous matter appears to be of more complex chemical composition than many other animal solids. By the action of hot alcohol, are obtained from it a quantity of albumen which remains undissolved, a quantity of oil which is deposited on cooling, and a quantity of extractive matter resembling osmazome, which remains in solution, along with some salts. A small quantity of phosphorus, and of sulphur, have also been obtained from brain. The whole of these, when perfectly dried, constitute only 20 per cent. of recent cerebral substance.

No movements have ever been seen in any small portion of nervous substance, even under the microscope, and when examined at the time when its peculiar functions were undoubtedly in exercise. But the whole brain and spinal cord, when exposed, may be seen to be slightly agitated by the impulse of the blood at each systole of the ventricles of the heart ; and more distinctly, to be elevated by the retardation, and depressed by the acceleration, of the flow of the blood in the great veins, in expiration and inspiration.

Besides the peculiarities formerly noticed as to the

arterial and venous circulation in the brain and cerebellum,—the effect of which is to diminish the impetus with which the blood enters the brain, and diminish the pressure on it from stagnation of the blood leaving it,—there is this farther peculiarity as to the circulation within the head, that, being carried on within a cavity with unyielding sides, it is protected from the pressure of the atmosphere, which acts on the vessels leading into it and out of it; and the consequence of this is, that the quantity of fluids within the cranium must be always almost exactly the same; no unusual quantity either leaving it, or entering it, without an equal quantity being introduced or expelled; unless some of the solids within the cranium either suffer compression (which they hardly admit), or else undergo alteration of quantity, which they cannot do quickly.

But although the whole quantity of fluids within the head can hardly be changed, within any short space of time, yet the impulse of the blood on the nervous substance, and pressure thereby caused, are no doubt very liable to change; and farther, various facts shew, that the relative proportion of blood in different parts of the encephalon, and even the relative proportion of blood in the vessels, and of serum exterior to them, are occasionally much and rapidly altered*.

Increased nutrition of the substance of the brain or cerebellum, after growth is over, cannot take place without disease, from the pressure on the cranium it

* KELLIE, Edinburgh Medico-Chirurgical Transactions, vol. i.

must occasion ; but appears evidently to occur in a particular diseased state, described as **Hypertrophy of the Brain**. Alterations of the nutritive process in this texture from disease are not uncommon ; but do not seem to take place so rapidly as to indicate frequent change of the substance of the brain in the progress of life. The facility of increased absorption appears in many cases of disease, where tumors grow on the surrounding membranes or bones, where blood is effused into the brain, and where fluid is effused into the ventricles, especially in the case of **Chronic Hydrocephalus**, where the sutures of the skull are enlarged ; for, in whatever manner it may be that the apparent unfolding of the convolutions in that case is accomplished, it is certain that a quantity of the substance intervening between the ventricles and convolutions must be absorbed away ; and that, in some such cases, the brain is considerably reduced in weight*.

It is certain, especially from the experiments of **CRUICKSHANKS**, **HAIGHTON**, **FLOURENS**, and **PREVOST**, that injuries of the nervous substance may be gradually repaired in the living body by materials which shall assume the true vital properties of this texture, now to be considered. An observation of **Mr MAYO** makes it probable, that the nerves at least are very dependent, for such power of reparation, on the vessels of surrounding cellular texture.

It is next to be observed, that **Nervous Matter**, in

* See **GORDON** on the Structure of the Brain.

the living body, possesses very peculiar and strictly Vital Properties, which are made known to us by the effects, on the functions of other organs, produced by physical impressions made on various parts of the Nervous System. These have been already briefly and incidentally noticed, but demand fuller consideration here.

I. Certain muscles are *directly excited* to contraction by irritation of certain parts of the Nervous System, without any impression being made on the muscles themselves. In regard to this general fact, the following things are to be observed.

1. The fact in question is fairly exemplified, only when those stimuli are applied to nervous matter in an animal stupified, or just killed, or to an amputated limb, when no effects of sensation embarrass the results.

2. The chief physical stimuli that answer this purpose, when applied to the Nerves, Spinal Cord, or Brain, are mechanical impulse or sudden pressure, chemical acids (the effect of which, in exciting muscular contraction when applied to *nerves* only, is unequivocally a vital phenomenon), and electricity or galvanism.

3. This effect of irritation of nervous matter is prevented from taking place whenever the communication, by sound nerve, between the point irritated and the muscle to be excited, is interrupted; but not when the communication between the point irritated and the brain is interrupted.

4. This phenomenon is observed, as has been already stated, on irritation of the nerves of certain muscles

only ; many muscular parts, especially the Heart and Intestines, having appeared in the experiments of HALLER, FONTANA, BICHAT, and many others, quite unaffected by irritation of their own nerves, and not distinctly excitable (though their movements may be modified), by irritation of other parts of the Nervous System. And from Mr MAYO's experiments particularly, it appears that the distinction between the muscles that are, and those that are not, excitable in this way, coincides very nearly, if not exactly, with that between muscles destined to voluntary and involuntary motion*.

5. This phenomenon is not seen on irritation of all the nerves of those muscles that are subject to it, but on irritation of certain of these nerves only. For it has been ascertained by the experiments, first of Mr BELL, and afterwards of MAGENDIE, BECLARD, MAYO, and many others, that hardly any muscular contractions can be excited by irritation of the posterior portions of the spinal nerves, or of the ganglionic portion of the 5th nerve, although strong contractions may be excited in this way through the anterior portions of the spinal nerves, and the 3d, 4th, anterior portion of the 5th, the 6th, portio dura of the 7th, 8th, and 9th central nerves. And Mr BELL has farther shewn, from what is seen on tracing the nerves of the face, that this difference does not depend on the nerves first mentioned not supplying muscles,—but that they supply muscles which they cannot excite†.

* MAYO's Outlines, p. 50.

† Phil. Transactions, 1826.

6. Muscles which have nerves from the spinal cord are excited to contraction, not only by irritation of their nerves, but also of the spinal cord itself, between the origin of these nerves and the brain. This irritation acts most powerfully on those muscles which have nerves from the immediate neighbourhood of the points irritated. But it has been further shewn by experiment, that this power of exciting muscular contraction, when itself irritated, does not reside in all parts of the spinal cord, but chiefly in its anterior surface, in a slight degree only in its posterior surface, and hardly at all in its internal parts*.

Irritation of the posterior surface of the spinal cord, and posterior roots of the spinal nerves, has appeared in some experiments to cause contractions, although feeble, confined to those muscles which *extend* the body and limbs, while irritation of the anterior surface, and anterior roots, acted chiefly, and more forcibly, on the flexor muscles†.

7. Muscular contractions have been very often directly excited, in experiments on animals, and in cases of injury or disease in the human body, by irritations of the parts of the nervous system situate within the cranium. But it has been long known, from experiments by ZINN, LORRY, HALLER, and others, that much of the brain and cerebellum may be injured without any such effects resulting; and more recent experiments, particularly those of LEGALLOIS, Dr

* MAGENDIE, *Journal de Physiologie*, tom. iii.

† BELLINGERI, *Archives de Medecine*, 1825.

WILSON PHILIP, and of FLOURENS, MAGENDIE, and FODERA, have led to the conclusion, that *no irritation of the Brain proper, or Cerebellum, is necessarily effective in producing muscular contraction*; but that this effect *uniformly* results from irritation of the *medulla oblongata*, and parts inferior to the corpora quadrigemina;—no doubt therefore of the fibres which ascend to the brain from the spinal cord through these parts; and that all irritation or injury of parts superior to this, excite muscular contraction only in so far as they extend directly or indirectly to, and affect, the medulla oblongata*.

When muscular contraction, or convulsive movement, is produced by injury or disease of either hemisphere of the brain or cerebellum, it has generally been observed on the opposite side of the body; and this has been ascribed to the decussation of the fibres at the lower part of the corpora pyramidalia. But any decussation of nervous fibres which can explain this fact, must take place higher up than the point mentioned; because this *crossing* of the effect of injury to the opposite side, has been observed, in the human body, from disease of the brain, in muscles moved by the seventh and ninth nerves, which arise nearer the brain than the decussation of the pyramids; and this phenomenon was not observed in the experiments of FLOURENS, in the muscles of the limbs,

* See particularly FLOURENS, *Recherches Experimentales sur le Systeme Nerveux*; FODERA in *Journal de Physiologie*, tom. iii.; and MAGENDIE, *do. do.*

when the sides of the medulla oblongata must have been irritated higher than that decussation*.

To the effects of injury or irritation, either of the spinal cord or brain, on muscular contraction, equally as to those of injury of individual nerves, it is an essential condition, that there be a communication, by sound nervous substance, from the point irritated, to the muscle that contracts.

8. In all these cases, the effect of injury of nervous matter, in exciting muscular contraction, is chiefly observed when it is produced *suddenly*,—gradual alteration, by injury or disease, even of the nerves or spinal cord, and still more of the brain and cerebellum, having often been observed where no convulsive motions had ever taken place.

II. The contractile power of many, perhaps of all, moving solids, is *liable to alteration* from physical causes acting on the Nervous System, which act, not as simple irritants, exciting contraction, but as stimulants or sedatives (*see p. 14.*) exalting or depressing the vital power. This effect of physical impressions on the Nervous System is chiefly seen in the involuntary muscles. It is imperfectly understood, and is with difficulty distinguished from the effect of sensations; but the following facts leave no room for doubt as to its existence.

1. It appears from the experiments of LEGALLOIS, that by a certain amount of mechanical injury of any

* *Récherches Experimentales*, &c. p. 115, *et seq.*

part of the spinal cord, the heart's action may be very much and instantaneously weakened, or even suddenly suppressed; and from the experiments of Dr WILSON PHILIP, that the same may happen from a certain degree of injury of the brain; but that from slighter injury, either of brain or spinal cord, inflicted on an animal in a state of insensibility, the heart's action is sensibly quickened*.

2. It appears also from the experiments of these authors, and especially of FLOURENS †, that great mechanical injury of the brain or spinal cord weakens the circulation in the capillaries sooner, and in a greater degree, than that in the large arteries, and even, that such injury of the spinal cord is often seen to affect immediately the flow of blood in the capillaries of those parts only, which have their nerves from the injured portions of the spinal cord.

3. Those mechanical injuries of the human body, which cause insensibility by general concussion of the system, at the same time manifestly and sometimes irretrievably depress the circulation; which effect it is reasonable to refer to an impression on the nervous system, because of the accompanying insensibility (which, as we shall see, implies affection of that system); and because it is just similar to the effect produced, in the experiments now mentioned, by injuries of the nervous system, without much general concussion of the body. In some such cases of concussion in the human body, as well as in such experiments,

* Experimental Inquiry, Exp. 20, 21, 22, 34, 38.

† Recherches Experimentales, p. 190 & 196.

violent convulsions of voluntary muscles attend the insensibility, and the failure of the heart's action ;-- the same impression on the nervous system which excites the voluntary muscles, acting as a sedative on the vital power of the heart.

The inordinate action of the bladder, and consequent incontinence of urine, which gradually ensue, in many cases, after injury or disease of the spinal cord, may also perhaps be regarded as an example of increased vital power, in a muscular part, from physical irritation of nervous matter.

It appeared in the experiments of Dr WILSON PHILIP, that the effect produced on the heart's action, by impressions made on the nervous system was nearly in proportion to the extent of nervous matter on which these impressions were made, and was nearly the same, in whatever part of the cerebro-spinal axis the injury was inflicted * ; and accordingly, both in the case of concussion, and in several diseases (*e. g.* in hydrocephalus and some cases of apoplexy), in which the heart's action is peculiarly influenced by changes in the nervous system, it may be observed that these changes extend to a large surface of nervous matter. But it is certain that the circulation in the arteries of a limb may be sometimes observed to be much weakened immediately after a paralytic stroke, when there may be no evidence of more than a very small portion of nervous substance being injured ; so that we cannot, as yet, lay it down as a principle, that this kind of

* Experimental Inquiry, p. 114 & 115.

influence on contractile parts, results only from impressions made on large portions of the nervous matter.

III. Although we gave reasons for thinking that Secretion and Nutrition are truly independent of nerves, yet several facts show, that physical impressions on, or injuries of, the nervous system, materially and variously *influence these functions*, as well as the circulation in the small vessels, which are their seat. This kind of influence of physical impressions on nervous matter, is also imperfectly understood, and not easily distinguished from the effects of mental acts; but it seems exemplified in the following instances:

1. The effect of section of the eighth nerve in the neck, in not merely suspending the secretion of gastric juice at the stomach (which is a somewhat ambiguous case), but also in exciting a degree of inflammatory action there; in preventing the usual effusion of mucus in the intestines, even when arsenic has been swallowed*; and, on the other hand, in exciting inflammation, and increasing the mucous secretion, in the lungs and bronchiæ†.

2. The effects (viz. inflammation, ulceration, and sloughing), produced on the eye-ball, and in some instances on the membrane of the nose, and on the gums, as was first ascertained by MAGENDIE, by section of the fifth nerve, which supplies these parts; and likewise, in a less degree, by section of the sympa-

* BRODIE, Phil Trans. 1814.

† WILSON PHILIP, l. c. SWAN, Essay on the Connexion between the Action of the Heart and Arteries and the Nervous System.

thetic nerve in the neck *,—effects which have also been seen, in some cases in the human body, from disease of the fifth nerve.

3. The inflammatory condition, with increased and altered secretion, of the mucous membrane of the bladder, in many cases of paraplegia, dependent on injury of the spinal cord.

The diminished nutrition and diminished secretions (*e. g.* by the skin), often observed in a limb which has been for some time palsied, by section of its nerve, or disease of the brain, may be thought to illustrate the same point; but these effects are perhaps sufficiently explained by the total inactivity of such a limb.

It is to be observed, that such effects as those now stated, on secretion and nutrition, have been observed only in certain parts of the body, and chiefly from injury of certain of the nerves supplying these. These are the sentient nerves of the parts in question; and the secretions which are changed, are generally such as are habitually excited by irritations producing sensation. It is still doubtful, whether the whole of the effects of these injuries on secretion and nutrition may not be explained by these considerations.

These statements of physical phenomena, however, illustrate the very peculiar powers, known only by their effects on other parts of the animal frame, which the Nervous System in living animals possesses. Only one theory, in explanation of these powers, appears to

* See DUPUY, *Journal de Medecine*, t. xxxvii.

deserve attention, viz. that which ascribes them to Galvanism, evolved in the animal frame, especially by the contact of nervous with muscular substance. It is known that, by the contact of these substances, galvanic phenomena, in a slight degree, may be produced; and that galvanism, however evolved, is a powerful stimulant of muscular contraction,—in an excessive degree, is a powerful sedative,—and has also appeared frequently to influence the capillary circulation and secretions.

It appeared also, in some experiments by Dr EDWARDS, that when the nerve and muscle of a frog were laid on a good conductor of electricity, irritation of the nerve had much less effect in exciting the muscle, than when they were laid on a non-conductor; which he ascribed to the galvanism supposed to be excited in the nerve being carried off by the conductor of electricity in the former case, and therefore not affecting the muscle*.

But whatever be the true explanation of this fact, the following general objections may be stated to the Galvanic theory of Nervous actions, such as we have hitherto considered them.

1. The causes which excite, in the highest degree of intensity, those changes in nerves by which muscles are excited (*e. g.* such causes as bruising with a probe, or pricking with a pin), seem quite inadequate to the production of a sudden and powerful galvanic influence.

2. We have seen that these causes do not act on

* Ann. des Sciences Naturelles, t. v.

all nerves, and through them on all muscles which they supply, but only on the nerves of certain muscles, and only on certain of these nerves.

3. We have seen that the power of exciting muscular contraction is so far from residing in nervous substance in general, that it resides on one surface of the spinal cord, and not on the other,—nor in its centre; nay, it resides in one part of a nervous fibre, in the medulla oblongata, and not in another part of the same fibre, half an inch higher in the brain.

4. While the changes in the nervous system, which excite muscles to contraction, take place only in certain parts of the nervous system, those which exalt or depress the vital power of muscles, appear to take place especially in others, and therefore affect especially other muscles; and the same cause (*e. g.* a violent concussion) which produces one of these effects exclusively in one nerve, may produce the other in another nerve immediately adjoining it.

These facts seem sufficient to show, that if it be galvanism which enables nerves to act on muscles in the living body, it is galvanism excited by means, and subjected to laws, very different from what we observe in examining the galvanic phenomena of dead matter. And this is equivalent to saying, that nerves act on muscles in the living body, in virtue of certain *vital powers*.

The most comprehensive and least theoretical general name that we can give to the changes in the nervous system that are referable to these powers, is that of Nervous Action, or Nervous Agency.

SECTION VIII.

OF THE ANIMAL FUNCTIONS IN GENERAL.

WE have attributed peculiar Vital Properties to the Nervous System, in consequence of the observation of certain merely physical phenomena. But these phenomena are the effects of injury and violence; and we have no reason to think that, in the natural and healthy state, those properties are frequently, if it all, called into action in this way. We believe the phenomena last stated to be only indications of the powers, which are given to the Nervous System in living animals, in order that it may be the seat, and the instrument, of Mental Acts.

These Mental Acts, and all the functions in which they have a necessary share, constitute the Animal Life, or Animal Functions, as distinguished by BICHAT and others. Some general observations on these functions may be introduced here, and will simplify the discussion of the remaining departments of Physiology.

I. As the words Sensation and Thought express simple ideas, it is impossible to define them; but no man can be at a loss as to their meaning, who is told that they apply to those changes which all men continually experience within themselves; and to which

all have been in the habit of applying such terms as Sight, Touch, Recollection, Judgment, Joy, Sorrow, Hope, Fear, &c. The word Mind is defined by saying, that it is that which undergoes the changes, or performs the acts, or exists in the states, to which these different terms are applied.

Neither does any man feel any difficulty in understanding the difference between what are strictly called Sensations, and what are called Thoughts, when he is told that the former term is applied to the changes which he experiences, when an impression is made on any of his external senses, and the latter to those other changes of which he is internally conscious, when no impression is made on his senses, *e. g.* Recollections, Emotions, or Judgments.

When we reflect on the essential nature of this difference, which every one must have habitually recognized, long before he has made it an object of attention, we find that the name Sensation is given to those changes which (in the adult state at least) are attended with an instantaneous conviction, that they depend immediately on a cause that is *independent of, and external to, the sentient mind* that undergoes the change. How this conviction of the independence of its immediate cause is acquired, *i. e.* in what circumstances it first arises in the mind, we do not now inquire; but it is a part of the Natural History of our mental constitution, and is the attendant, and the essential characteristic, of that mental change, to which we give the name of Sensation.

The immediate cause, independent of, and external

to, the sentient mind, to which we naturally ascribe the excitation of sensation, is what we call Matter ; and we attribute to it different qualities, corresponding to the different sensations which it excites in our minds ; or, as it is otherwise expressed, we *perceive* it, and its qualities, by our senses.

If this account of the strict meaning of the terms Mind and Matter be correct, no more need be said in order to shew, that it is illogical and absurd to speak of these, otherwise than as separate existences ; because any one, who has correctly apprehended the meaning of the two terms, has already formed the judgment, that the one is independent of the other.

The one term is applied to the individual being, which we naturally and intuitively judge to be the *subject*, or *seat*, of those changes which we call Sensations or Thoughts ; it is that which actually exists in the different states, to which we give these names ; and we cannot apply the term to any thing which we judge to be separate from, and independent of, these feelings. The other is known to us only as the *object* of sense : the cause, judged to be independent of our sentient minds, of certain of the changes of which these minds are susceptible ; and unless we have already formed the judgment of its independence, we cannot apply the term. Those who distrust that judgment, will not believe in the existence of Matter ; but those who believe in the existence of Matter, (unless they can explain how they got that notion, otherwise than as above stated), cannot, without absurdity, identify it with Mind.

The same facts are expressed by saying, that for the existence of Matter we have the *Evidence of Sense*, for that of Mind the *Evidence of Consciousness*; and that we inquire into the one by *Observation*, and into the other by *Reflection*. For the existence of any other sentient and thinking minds but our own, we never can have either of these kinds of evidence; it is not known to us, either by consciousness or observation, but is always a matter of *inference*.

It is to be observed, then, that we give the name Object of Sense, to those things only which we judge, at the moment when we apprehend their existence, to be external to, and independent of, the sentient mind that perceives them; and we distinguish the acts themselves, of Sensation and of Thought, from any attributes of matter, simply because they are not objects of sense; and accordingly, we distinguish them from all attributes of matter, not in Man only, but throughout the whole of Creation; and say, without hesitation, that every living being in which we judge that any act of Sensation or Thought takes place, *i. e.* that every Animal, is the residence of Mind.

When we speak, as physiologists generally do, of Sensation and Thought as Functions of the Nervous System, it must be obvious, from what has now been said, that we use this term Function in a sense somewhat different from that in which we apply it to other textures or organs of the body; because, in all other instances, we apply the term to a change which may be made, in some way or other, perceptible to our

senses ; and the changes now in question are, from their very nature, imperceptible to our senses ; and known to each of us, as existing in any living body but his own, by inference only.

When we say that Sensation and Thought are Functions of the Nervous System, we mean only that this system *furnishes the conditions* under which Sensation and Thought in the living body take place ; and when we say that Instinctive and Voluntary Motion are, in part, functions of the Nervous System, we mean that this system *forms the Medium*, through which certain acts of mind, called Instincts and Volitions, are enabled to excite certain muscular contractions.

How it happens, that, under certain conditions of the Nervous System, in the living body, the different mental phenomena should be connected with it, we have no reason to expect that we ever shall know. When we examine the structure of the Brain, we see nothing which could have led us to anticipate that it would be the residence of Sense or of Intellect ; and when we reflect on the powers of the human mind, and compare them with the indications of a Superior Intelligence which we see around us in the world, it appears inconceivable to us that they should be linked with the existence, grow with the growth, and change with the changes, of a piece of soft white matter. But in all other inquiries into the works of Nature we meet with ultimate facts, that are equally beyond our comprehension.

The true objects of this department of Physiology are only these,—to distinguish and arrange the differ-

ent Mental Phenomena themselves ; to ascertain the conditions in the state of the Nervous System, on which their manifestation depends ; and to trace the effects on the various functions of the body, which result from them.

II. Sensations may be divided into those which are felt in consequence of impressions made on individual organs only, such as Light and Colour, Smells, and Sounds, called the Higher or Special Sensations ; and those which are felt pretty generally over the body, as Touch, Heat, Cold, Pain, to which the name of Common Sensation is given. Acts of Thought, again, may be divided into those which not only proceed from no immediate cause, but are followed by no immediate effect, external to the mind itself,—such as Recollections, Judgments, Acts of Imagination ;—and those which are immediately followed by changes in the body. Of this last class, Instincts and Volitions, which are uniformly followed, in the natural state, by contractions of certain muscles, are the most unequivocal instances ; but certain Sensations and Emotions are likewise naturally followed, either by muscular contractions, or by alterations in the circulation, or in the secretions of various organs. We do not enter as yet into any details regarding these mental acts ; but the distinctions now stated are easily recognized.

That the Nervous System is essentially concerned in, or furnishes necessary conditions to, all these phenomena, we conclude from the following facts :

1. It is shewn by unequivocal experiments, and by

the uniform result of observations on the human body, that Sensation, in every part of the body, and that the effects of Instinctive or Voluntary efforts, on the muscles which these affect, are essentially dependent on Nerves distributed to those parts, and are prevented from taking place, when the communication of these nerves with the cerebro-spinal axis is interrupted, by compression or destruction of the nerves. How the different portions of these nerves are concerned in, and how far the Spinal Cord and Brain are essential to, these functions, will be considered afterwards.

2. Although we cannot say that the indications of mental phenomena, in organized beings, coexist exactly with the existence of a Nervous System, yet in general, throughout the animal kingdom, and especially in vertebrated animals, which have a spinal cord, similarly formed as the human, and organs corresponding to brain and cerebellum,—the greater development of the Nervous System is proportioned to the greater perfection in which the acts of Sensation and Thought take place; and the greater development of the Brain proper in particular, to the greater intelligence of the animal.

3. All Sensations, Thoughts, and their effects on the body, are liable to alteration from injury or disease of the nervous system, especially of the Brain and upper part of the Spinal Cord; and there are certain injuries of these parts, to be afterwards specified, which never fail to put a stop to all indications of the most important mental phenomena.

4. There is no other texture, upon which the mental

phenomena show any dependence,—any alterations which they undergo, in consequence of injury of other textures, being always referable to an injurious influence transmitted, directly or indirectly, from these other textures to the nervous system.

5. The changes produced in different organs of the body, by the different acts or affections of the mind, correspond very nearly to the changes which are observed in these organs (*e. g.* muscles, voluntary or involuntary, glands, &c.), from the physical injuries of the Nervous System, already considered.

We can have no doubt that the Nervous System is fitted for the purposes which it serves in regard to the mind, by the peculiar Vital Properties with which we have found that it is endowed; and which are so far exemplified by the effects of physical irritation or injury above noticed. But these vital properties are known to us only by their effects; either on the mind, on the one hand, or on the other bodily organs, on the other.

III. Certain general conditions may be stated, as essential to the existence of these vital properties in all parts of the nervous system.

1. The most important is, the circulation of Arterial Blood through the nervous matter,—a condition necessary for all functions, but the interruption of which is more speedily injurious to this than to any other; and the necessity of which condition will appear distinctly when we treat of Respiration.

2. Various facts show, that any sudden alteration

of the Pressure, to which the nervous matter is subjected, are frequently followed by diminution or suspension of all the animal functions; as, *e. g.* in the case of insensibility, produced by bleeding in the erect posture; or by tapping, without bandaging the abdomen, &c.; and again, in the case of any such mechanical compression of the brain as shall especially affect the medulla oblongata. It seems probable, that to the sudden alteration of pressure on the nervous substance, we should refer the fact, that drawing off the small quantity of fluid that exists, in living animals, beneath the arachnoid, and in the ventricles, enfeebles or suspends the animal functions*.

3. Various facts pretty clearly indicate, that the Nervous System is not passive during the performance of any of the animal functions connected with it, but undergoes changes in which some (although imperceptible) Movement of its particles, is probably concerned. Of this kind are the following:

An impression from an internal physical cause; made on a part of the Nervous System, will sometimes excite the same kind of sensation as an external impression on certain organs of sense. Again, the sensation produced by an impression on an organ of sense, lasts longer than the application of the external cause, as is particularly obvious in regard to the sensation of Light; and sensations which have forcibly engrossed the attention, are often irresistibly obtruded in a less degree of intensity, especially during darkness and silence, long after their causes have been removed.

* MAGENDIE, *Journal de Physiologie*, t. vii. et viii.

Farther, it may be observed, that both Sensations and Volitions, as connected with the Nervous System, present many striking analogies to the phenomena of muscular contractions; they undergo changes from repetition and habit, similar to those formerly noticed in contractile parts; and, in particular, the nutrition, of the nerves of sense at least, is increased by their habitual employment, and diminished by their inactivity. Excessive exertion of any of the animal functions induces morbid phenomena, which indicate derangement of the circulation in the parts of the nervous system most connected with them. These functions require, equally as most muscular contractions do, intervals of relaxation or suspension, which they enjoy during sleep; they are gradually altered, nearly in the same way as muscular contractions are, in the progress of life; and various poisonous or medicinal substances taken into the circulation, affect the animal functions in a way analogous to that in which they affect involuntary muscular contractions.

IV. It is now well ascertained, not only that the Vital Properties, which shew themselves on physical irritation of nervous matter, vary in different parts of the system, but that the Mental Phenomena, which are connected with different parts, are quite distinct; and considerable progress has been made in the *appropriation* of the parts of the Nervous System to the different mental phenomena. The parts which are appropriated to Sensation, and to Instinctive or Voluntary Motion, are nearly ascertained; and the

statements to be made on that subject may be introduced here. Those appropriated to other mental acts are less clearly distinguished, and what is known as to them will appear in the account to be given of the functions in which these acts are concerned.

1. As to the office of *Nerves* in Sensation and Voluntary Motion,—it is known that they are essentially concerned in these functions (see p. 157). But it is also ascertained that there are *no sensations*,—not even such as are common to all parts of the body,—which are *felt in all nerves, i. e.* in consequence of impressions made on all nerves; but that there are, in all parts of the body, certain nervous fibres or filaments destined to sensation, and others incapable of exciting sensation.

It has appeared, from the numerous experiments, first of Mr BELL, and since of MAGENDIE, BECLARD, MAYO, and many others,—confirmed in a great measure by observations of cases of disease in the human body,—that it is by irritation of the posterior roots of the spinal cord, almost exclusively, that indications of pain (*i. e.* of common sensation) are excited; and that it is by section of these roots that insensibility of the parts supplied by these nerves is produced. And on the other hand, as it is by irritation of the anterior roots of the spinal nerves that muscular contractions are chiefly or almost solely excited, so it is by section of these roots that muscles are palsied, *i. e.* that voluntary efforts are rendered ineffectual for their excitation. Hence it appears, that it is only in consequence of different filaments of nerves, with different

endowments, being bound up in the same sheath after they leave the spinal canal, that these spinal nerves generally appear to minister both to sense and to voluntary motion.

Again, similar experiments and observations shew still more clearly, that those of the cerebral nerves which were mentioned as capable of exciting muscular contractions when themselves irritated, (the 3d, probably the 4th, the anterior branch of the 5th, the 6th, Portio Dura, and 9th), are the motor nerves, by which the muscles of the eye-ball, lower jaw, face, and tongue, are moved in obedience to the will; and that the ganglionic portion of the 5th is the sensitive nerve, which gives, exclusively, common sensation to the face, eye-ball, mucous membrane of the nose, mouth, and tongue.

This great sentient nerve is easily shewn to be in communication with the posterior columns of the spinal cord; and the motor nerves, above mentioned, would seem to communicate with its anterior columns. There is an exception, however, in the case of the 4th, any connexion of which with the anterior columns of the spinal cord is very doubtful. And it is farther to be observed, that all the larger portions of the 8th nerve, which seems to be more connected with the posterior than the anterior columns, appear from experiment to be nerves both of Sensation and of Motion*; and the statements of BELLINGERI and others show, that the appropriation of the nervous

* MAYO'S Anatomical and Physiological Commentaries, No. 2.

filaments, arising from the different surfaces of the spinal cord to motion, and to sensation, is not yet ascertained to be absolutely exclusive; perhaps because the separate offices of the different columns of the spinal cord have not been distinguished with sufficient minuteness.

While it thus appears that the sensations common to all parts of the body are felt only through certain of the nerves, it is also certain that the peculiar sensations which have special organs appropriated to them, Smell, Sight, and Hearing, are felt only through their peculiar nerves, the 1st, 2d, and portio mollis of the 7th (or a part thereof); and even, from the experiments of MAGENDIE, that these nerves are incapable of exciting common sensation; their sensibility being confined to the qualities of external things to which they are appropriated, and the common sensations of the organs in which they are found depending on the 5th pair*.

The peculiar sensations of these special organs have been found to be impaired by injury of the branches of the 5th nerve entering them; but this does not prove, that the injuries of that nerve have more than an indirect influence on these sensations, perhaps dependent on the alteration which its injury produces on the nutrition of these parts (see p. 147). It has been thought, that in some animals the organs of some of the peculiar senses are supplied from the 5th pair exclusively, and the peculiar sensations felt only

* Journal de Physiologie, 1824 and 1825.

through them ; but this observation is probably erroneous*.

No observations have yet shewn, whether or not the ganglia, found very generally throughout the animal kingdom, on the roots of the nerves of common sensation, have any necessary connexion with their sensitive power. But no such arrangement is found in the nerves of the special senses ; and the sympathetic nerves, and its ganglia, give but obscure indications of sensibility on irritation. It is obvious, from what we see of some of the cerebral nerves, that the union of motor nerves in plexuses is by no means necessary to the power of the will over them.

2. There is some difficulty as to the necessity of the intervention of the Spinal Cord in Sensation and Voluntary Motion. It has been generally observed, in experiments on animals, and in cases of injury in the human body, that destruction of the spinal cord, above the origin of a nerve, equally destroys sensation and voluntary motion in the parts supplied by that nerve, as section of the nerve itself ; and hence it has been concluded, that some change is necessarily propagated *upwards*, along the nerve and spinal cord, to the brain, in the case of Sensation, and *downwards* along the spinal cord and nerve, from the brain, in the case of Voluntary Motion.

But it has been observed by different physiologists, HALLER, WHYTT, LEGALLOIS, MAYO, &c., that

* See SERRES, Anat. Comparée du Cerveau, Art. Nerf. Trijumeau, and GEOFFROY ST HILAIRE, sur la Vision de la Taupe ; Revue Médicale, tom. iv. p. 138.

even in warm-blooded animals, after the spinal cord has been divided, certain movements of the inferior extremities have been made on irritation of the skin of these parts, which appear to indicate some remains both of sensation and of voluntary power in the parts thus severed from the brain ; and in the cold-blooded animals, it is known that the Nerves and Spinal Cord generally suffice for giving some indications, both of sense and voluntary motion, when separated from the Brain and Cerebellum. In the human body one case of division of the spinal cord by wound, and several of more or less complete interruption of its continuity by disease, have been recorded, in which absolute loss of sense, and of voluntary power, were not observed, and were thought not to have occurred before death*.

Such cases have led some physiologists, at different times, to think, that the changes essential both to sensation and voluntary motion, may be truly *confined to the nerves*, and only *liable to a noxious influence*, transmitted downwards, from injury or disease of the Spinal Cord or Brain ; which noxious influence, although it very generally follows, may not necessarily follow, such injury or disease.

But the following considerations, long ago urged on this point by HALLER†, seem sufficient to show that the common opinion of the *transmission of some change*, through the spinal cord, *upwards* to the

* See DESAULT, Journal de Chirurgie, t. iv. ; OLLIVIER sur la Moelle Epiniere ; VELPEAU in Archives de Medecine, 1825.

† Elem. Physiol. t. iv. p. 295, *et seq.*

brain in sensation, and *downwards* from the brain in voluntary motion, is well founded.

First, In the common case, of loss of Sensation and voluntary power after section of the spinal cord, the lower segment of the cord, and nerves arising from it, are still perfectly capable of exciting contraction of the muscles of the lower limbs, when themselves physically irritated ; which implies, that the loss of voluntary power, after the section, is not because the nerves of the lower limbs cannot act on the muscles, but because the brain, or upper part of the spinal cord, cannot act on the nerves ; and therefore, that when the communication is entire, the brain, or something within the cranium, does act on the nerves.

Secondly, After division of the spinal cord, as after amputation of a limb, pains are often felt, distinctly referred to the place below the section ; which implies, that the usual sensations of these parts had been dependent on changes extending at least as high as the section. Farther, at the will of the person, in such cases, the usual effort to move the limb is made,—seems to the person to be effective on it,—and is truly effective on such muscles, supplied from above the section, as used to be associated with those now palsied ; which implies, that the effort which was wont to be effectual on the whole of these muscles, had been attended by a change in the parts of the nervous system higher than the section, which had been transmitted downwards.

As these statements apply to sections in *any part* of the Spinal Cord, it can hardly be doubted that the

propagation or transmission of a change along the nervous matter, to and from the brain, in the ordinary case of Sensation and Voluntary Motion, does take place; but it does not follow from this, that no degree of sensation or of voluntary action, consequent on sensation, can possibly take place when the nervous communication with the brain is in any manner interrupted. In some of the lower animals (chiefly cold-blooded), there can be no reasonable doubt of the possibility of this. In most of the cases of the kind recorded as having occurred in the human species, inaccuracy of observation, before or after death, may be suspected; but it is also possible that a less degree of the mental acts may be connected with the inferior portions of the spinal cord; or that absolute continuity of nervous substance is not essential to the transmission of nervous agency; particularly as we have reason to believe that that agency can affect blood within vessels, and as the effects of section of a nerve, when the cut ends are laid in contact, have, in various instances, appeared less injurious than the effects of section, with loss of substance*.

3. It is now satisfactorily ascertained, that no part of the Brain, higher than the Corpora Quadrigemina, nor of the Cerebellum, is essentially concerned in Sensation. All the parts superior to this have been frequently injured, by many physiologists, in warm-blooded animals; and have been wholly removed, even in warm-blooded animals, by DU VERNEY,

* WILSON PHILIP, Philosophical Transactions, 1822.

CHIRAC *, LORRY † LE GALLOIS, FLOURENS, FODERA, and MAGENDIE ; and, if the remaining nervous matter was kept free from compression, all the usual indications of sensation remained. Farther, in these cases, such Instinctive or Voluntary efforts as were made, were still effectual in exciting muscular contractions of all parts of the body.

It appears from these experiments, that if we regard the spinal cord as reaching to the Corpora Quadrigemina, and giving origin to all the nerves, (see p. 133), we are to attribute to it, and to the nerves arising from it,—but especially to its highest portion, the medulla oblongata, and fibres extending thence to the crura cerebri,—all the physical conditions that are necessary, in order that Sensation may be felt, and that Voluntary efforts may excite muscular contraction ; the mental stimulus of Volition being just on the same footing, in regard to muscular contraction, as a physical stimulus applied to the medulla oblongata. (See p. 142.)

Accordingly, instances have been recorded by Mr LAWRENCE ‡, and others, of infants of the human species, born alive, obviously capable of sensation, and of certain instinctive actions, in whom the nervous system terminated at the Tuber Annulare.

It has also been distinctly proved by experiments by LEGALLOIS and FLOURENS, that two of the sensations which may be called peculiar and special,

* Phil. Trans. 1697.

† Mem. présentées à l'Acad. des Sciences, t. iii.

‡ Medico-Chirurgical Trans. vol. v.

those of the eye and of the lungs, are necessarily connected only with those portions of the contents of the cranium, which lie close at the origins of their nerves.

It will appear afterwards, with what intentions, as regards sensation and voluntary motion, the brain and cerebellum are superimposed on the spinal cord. It will appear that they are useful, not in order that Sensations may be felt, but that they may be remembered, and availed of for useful purposes ; not in order that Volitions may act as stimuli on muscles, but that they may act on them at the right times, and in the requisite variety of combinations and successions.

The facts now stated enable us to understand, without difficulty, so far as mere sensation and the power over the muscles are concerned, how it should happen that some injuries or diseases of the brain proper, or cerebellum, should affect these functions materially, and others not at all ; because all injure these functions only in so far as they affect the medulla oblongata ; and it is easy to understand, that the effect of some such diseases or injuries may extend downwards to the medulla oblongata, and that of others not. And this is well illustrated by FODERA's experiments on the comparative effects of *lateral* and of *vertical* compression of the brain or cerebellum *.

V. It is necessary, before proceeding to the functions of Respiration and Digestion, to distinguish more accurately the different kinds of mental acts,

* Journal de Physiologie, t. iii.

which, operating through the spinal cord and nerves, excite muscular contraction.

1. Voluntary motions are those which are not only preceded by a mental act, and attended by a sensation that informs us of their performance, but accompanied besides by a conviction, that we may perform them or not as we please. This conviction is the characteristic of that mental act which we call Volition. How this notion is formed, and whether or not it may be deceptive, we do not now inquire; its existence is all that concerns us at present.

2. There are likewise in the healthy state, motions of voluntary muscles which are quite involuntary, of the performance of which we are conscious, but which we have no direct power of controlling, and often strive in vain to counteract or conceal. These, on examination, appear always to be preceded, and we have every reason to think that they are caused, either by Sensations, as in the case of Sneezing, Coughing, Vomiting, &c., or by those mental acts or affections which we call Emotions, as in the case of Laughter and Weeping.

3. The former class of actions are divided into those which are more strictly Voluntary, and those which are properly called Instinctive. The distinction of these lies in this circumstance, that in the former case, we have a distinct object in view; our actions are not only prompted by an act of which we are conscious, but directed to an end which we desire; but in the latter case our actions are consequent indeed on a sensation, but prompted by a blind impulse,

the consequences that are to follow from the action being either unknown or disregarded ;—as in gratifying the appetites, guarding the eyes from danger by closing the eyelids, or the body from falling by throwing forward the hands.

The instinctive actions are closely connected with the motions that proceed directly from sensations on the one hand, and with the strictly voluntary motions on the other. In the adult human being it is hardly possible to distinguish them from movements that have been prompted by reason, and become habitual ; but in the infant, and in the lower animals, they are easily distinguished, chiefly by two marks, *1st*, That they are performed always in the very same way ; whereas actions that are strictly voluntary and prompted by reason, although directed to the same ends, vary considerably in different individuals. *2dly*, That, however complicated the movements, the truly instinctive actions are performed equally well the first time as the last ; whereas even the simplest of the strictly voluntary movements require Education.

The phenomena and effects of Instinctive and Voluntary motions will require a separate consideration afterwards ; but it was necessary here, as a preliminary to the subjects of Respiration and Digestion, to specify the different modes in which, through the intervention of mental acts, muscular contractions may be excited in the living body.

These two functions are common to the whole animal kingdom, and their purpose is to maintain the requisite quantity and purity of the nutritious fluid, which

is essential, as was already stated, to the vital powers of the moving solids, and to the vital action of all other parts, and especially of the Nervous System.

These purposes are fully accomplished in vegetables, and in the foetus *in utero*, before there are any indications of sensation ; and even in the adult animal a great part of the changes, which come under the heads of Respiration and Digestion, belong strictly to the Organic Life. But in all animals the reception of food into the digestive organs, and in all vertebrated animals, and many of the inferior orders, the reception of air into the respiratory organs is accomplished, in the adult state, by movements which are excited through the intervention of Sensations and of Instincts or Volitions ; and therefore the commencement of the processes of Respiration and Digestion in them belongs to the province of Animal Life, and may be shewn to be dependent on the Nervous System.

SECTION IX.

OF RESPIRATION.

THE arterialization of the blood by exposure to air is of such importance in the animal economy, that in man, and the animals the most analogous to man, its interruption for a few minutes is fatal. In comparing the different classes of animals, especially the great divisions of Warm-blooded and Cold-blooded, and still more remarkably in comparing the different states of those animals which hybernate, or are subject to periodical torpor, it is observed that the strength and rapidity of vital contractions, the energy of the functions of the Nervous System, the elevation of the animal heat, and, in general, the intensity of all the vital functions, are nearly in proportion to the degree of action that takes place between their blood and the air.

But it is not yet fully ascertained, whether this action is merely of the nature of excretion from the blood, of something which would be noxious if retained, as is the case with the discharges of bile and of urine ; or whether any thing is necessarily added to the blood from the air, which assists in qualifying it for its office in the system ; and therefore it is still doubtful whether the intensity of the vital functions, that goes along with the high degree of this action of

the atmosphere on the blood, is to be regarded as its cause or its effect.

One chemical change on the air is seen from the action of the fluids of all living beings, viz. the disappearance of more or less of the oxygen, which forms about 20 per cent. of its constitution, and the increase of its carbonic acid, which forms less than 1 per cent. of it; and the volume of the carbonic acid added has always appeared to approach, and in many cases to equal, the volume of oxygen lost.

But in vegetables, when living and exposed to light, another chemical change is effected on the surrounding air, viz. the removal of part of its carbonic acid, and the substitution of oxygen, or what is usually called purification of the atmosphere.

It has not yet been ascertained, whether this purifying influence of vegetables does or does not exceed the vitiating influence of the exhalation or formation of carbonic acid, which is likewise seen in them; but it is certain that the whole effect of animal life on the atmosphere is vitiating, *i. e.* to cause addition of carbonic acid to it; and other processes, always going on at the earth's surface, have a similar effect; and yet the whole quantity of carbonic acid in the atmosphere is not found to increase. There must, therefore, be some purifying cause continually in operation to compensate for the continual vitiation; and we know of none acting on a large scale, except the influence of living vegetables.

Farther, it appears certain that vegetables may grow, and the quantity of carbon in them gradually increase,

when they are supplied with air and water only, and can derive no supply of carbon from the earth*.

These circumstances render it highly probable that living vegetables, on the whole, decompose more of the carbonic acid of the atmosphere than they form; and therefore both purify the atmosphere, and derive part of their nourishment from it.

The facts which favour this opinion have been ingeniously and judiciously connected by M. ADOLPHE BRONGNIART †, with observations made on the remains of organized substances on the crust of the earth, which shew that an extensive vegetation must have existed, at a time when there were few or no animals, and that subsequently many cold-blooded animals inhabited the earth and sea, before there were any warm-blooded animals. If we suppose the atmosphere to have contained originally a much larger proportion of carbonic acid than now, it may be inferred, from what has been said, that it would enable vegetables to grow before any carbonaceous soil existed, and would be gradually purified by their growth; and the degree of vitiation which would result from the respiration of the cold-blooded animals, might probably be more than compensated by the purifying influence of the vegetables. After the purification had been carried to a certain length, the atmosphere would become fitted for the respiration of warm-blooded animals, which require a fuller supply of oxygen, and exhale carbonic acid more abundantly; and, from the time

* SAUSSURE, *Recherches Chimiques*, p. 50, *et seq.*

† *Annales des Sciences Naturelles*, tom. xv.

of their creation, it would appear that the processes which purify, and those which vitiate, the atmosphere, are pretty nearly balanced.

But whatever the provisions may be, by which the average purity of the atmosphere is maintained, notwithstanding the continual additions of carbonic acid which it receives from the respiration of animals, the importance of the process to animal life is illustrated by the adaptation of the respiratory organs, in different animals, to the degree, and the mode of action, of the air on their fluids. This adaptation is determined chiefly by the following conditions.

1. By the degree of density or solidity, and complication of the textures composing the animal. When the structure is simple, or the materials light and porous, air is admitted freely into all parts of the animal, and no part of the body is appropriated to the reception of air. This is the case in Zoophyta and Insects. But where the structure is complex, and some of the textures dense and impervious to air, a separate respiratory organ, and along with it, as before observed, a circulating system, are required.

2. Where these organs exist, their nature is determined by two conditions,—*first*, by the amount of vital energy which the animal is to possess, and proportional amount of action of the air on the blood, for which provision is to be made; *secondly*, by the medium in which it is to exist. When it inhabits air, and is warm-blooded, it breathes by lungs, and has a double circulation, *i. e.* all its blood, after completing the circulation through the body, is sent to the

lungs. This is the arrangement in the Mammalia and Birds. When it inhabits air, and is cold-blooded, it breathes by lungs, but has a single circulation, *i. e.* sends only part of its blood to the lungs, and that part is mixed with what returns from the rest of the body. This is the mode of respiration of Reptiles. When the animal is to inhabit water, it acts on the air contained in that water, by gills or analogous organs. But as this action is necessarily slight in comparison with that which takes place in lungs, the whole blood is sent to the gills, and the animal nevertheless is cold-blooded. This is the mode of Respiration in Fishes and most of the Mollusca, the Crustacea, &c.

The smaller number, and larger size, of the particles of the blood in cold-blooded animals, are likewise adapted to the less degree of action which is to take place between it and the air; and various additional provisions, adapted to the circumstances of different classes of animals, farther illustrate the same principle. Thus birds, in which there is occasion for great muscular energy, and therefore for a full supply of air, have not only lungs, but likewise tubes which admit the air into contact with their blood, in almost all parts of their bodies. Reptiles, which breathe by lungs, but are frequently under water, or in very impure air, have lungs provided with vesicles of such size as to serve as reservoirs of air for these occasions. On the other hand, certain fishes and crustaceous animals, which breathe by gills, but are often for some time in air, have reservoirs of water for their gills to act on

during the time of their abode in air*. Warm-blooded animals which habitually dive in water, seem to be enabled to dispense with the inspiration of air, at these times, by the great quantity of their blood, and by the great size of their large veins, permitting it to accumulate there, when, in consequence of suspended respiration, it cannot freely penetrate the lungs†.

In the human body, the mechanism by which the regular application of the air to the blood in the lungs is secured, is well understood; but there is still some difficulty as to the precise nature of the chemical change; and as to the mode in which the cessation of that change at the lungs affects the rest of the system.

I. The first step in the process is a Sensation in the breast, felt when the chest is at rest, especially after expiration, caused by venous blood moving through the lungs, amounting quickly to extreme anxiety if not relieved, and uniformly prompting the complicated action of inspiration, by which it is immediately appeased. The influence of the sensation, in exciting the acts of respiration, even during sleep, and during coma, is proved by the increased energy and frequency of these acts, which may be produced by any means of obstructing the free access of air to the lungs, and so augmenting the intensity of the

* CUVIER and DUMERIL, Rapport sur le Memoire de AUDOUIN et MILNE EDWARDS, Annales des Sciences Naturelles, tom. xv.

† EDMONSTONE, in Phil. Magazine, August 1827.

sensation *. And other Sensations, particularly those caused by certain irritations of the nostrils, or by cold suddenly applied to the face or breast, equally excite the act of inspiration.

This action being, in the natural state, caused by a sensation at the lungs, is necessarily dependent, in the first instance, on the sensitive nerves of the lungs, and especially on those which most directly communicate between the lungs and the medulla oblongata, viz. the eighth pair. Accordingly, after section of these nerves, the actions of Respiration, although not stopped (probably on account of the other communications, through the sympathetics and spinal cord, which the lungs have with the brain), are yet in general performed slowly, and always imperfectly †. And the experiments of LEGALLOIS and FLOURENS have shewn unequivocally, that by injury of the part of the medulla oblongata, from which these nerves originate (and of that alone, of all the contents of the cranium), all attempts at inspiration are finally arrested; no doubt because a final stop is put to the sensation which prompts them.

The objects of the movements which the sensation excites are, to enlarge the cavity of the chest in all directions, and at the same time to hold open the passages by which the air is to enter it.

The cavity of the chest is capable of change of dimension in all directions, in consequence of the dia-

* See WHYTT on Vital Motions, sect. 8.

† See particularly BRONIE, Phil. Trans. 1812.

phragm, which forms its lower boundary, being itself a moveable and contractile part, and in consequence of the ribs, which enclose the greater part of it, being so articulated with the spine, as to be susceptible of motion upwards and downwards.

The chest is lengthened in the act of inspiration, chiefly by the contraction and descent of the diaphragm, especially of its fleshy lateral portions, which, from being convex towards the chest, are flattened, and slightly depress its central tendinous part. It cannot pull down the ribs, because they are fixed, at the moment, by the contraction of the intercostal muscles. But the elongation of the chest is partly also effected by the action of those muscles of the front and sides of the neck, which pull the highest ribs towards the neck and head.

The chest is rendered broader and deeper in the act of inspiration, by the elevation of the ribs; because these are both curved outwards, and sloped a little downwards; and therefore, when raised nearer to a right angle with the spine, enclose a larger space within the arches they form transversely, and also project, and push the sternum slightly forwards.

The elevation of the ribs is caused partly by the action of the two strata of intercostal muscles, because the lower ribs are more moveable than the higher, and therefore must be drawn towards the higher, when the whole of these muscular fibres contract; but the motion of the ribs, in inspiration, especially when forcible, is assisted by the action of the diaphragm forcing upwards the lower margin of the chest,

at least when the abdominal viscera oppose much resistance to its descent *; and also by the combined action of those muscles which draw the scapulæ towards the cervical vertebræ and head, and of those which draw the ribs towards the scapulæ.

The glottis is held open, during inspiration, by the action of the muscles connecting the arytenoid to the thyroïd and cricoid cartilages. The nostrils are slightly expanded, in forcible inspiration, by the muscles attached to the alæ of the nose. The Velum Pendulum Palati is raised and stretched by its own muscles, when inspiration is made chiefly through the mouth; and the lower jaw is often slightly depressed by the contraction of the muscles between it and the os hyoides.

Of these muscular actions, those of the diaphragm and intercostals are probably all that are employed in healthy and easy respiration; and in various circumstances, when there is an obstacle to the action of one of these, that of the other is found to suffice; but when the sensation prompting inspiration is intense and long-continued, all the other movements take place simultaneously, and with perfect precision, independently of all experience. The force, rapidity, and frequency with which they are performed are all under the command of the will, and they may even

See MAGENDIE, *Precis Elementaire*. The protrusion of the lower margin of the chest, apparently by the action of the diaphragm, is very obvious in the deformed chests of rickety children, when affected with dyspnœa, and seems to be the cause of the great depression of the ribs at the sides of the chest in such children.

be performed in conjunction or separately, except when the sensation that prompts them is unusually intense, in which case it supersedes all efforts of the will.

The movement of Inspiration is immediately succeeded by that of Expiration, partly no doubt because of the natural tendency of muscular contraction to alternate with relaxation, but partly also because somewhat of the uneasy sensation in the chest is felt when we rest on an inspiration, and is relieved by expiration; probably in consequence of the motion thereby given to the air along the surface of the membrane, where the capillaries carrying the venous blood ramify.

The act of ordinary expiration hardly requires any muscular effort, but is the natural effect of cessation of the contractions by which inspiration was effected. The state of the thorax, after an ordinary expiration, is that which is determined by the physical structure and properties of the parts, and the pressure of the atmosphere, and has therefore been called the natural state of the thorax; and the return to that state, after the effort of inspiration is over, is produced by the elasticity of the parts concerned,—of the lungs themselves, of the parietes of the abdomen, of the cartilages of the ribs, and more especially of the ligaments that connect the ribs to the spine.

But when the sensation caused by venous blood in the lungs is intense,—when certain other sensations in the trachea or bronchiæ, or certain emotions, are felt,—or when a certain voluntary effort is made,—the diaphragm and ribs are brought back to their position,

after inspiration, with force and rapidity; and, by a continuance of the same action, the thorax is contracted within its usual limits. This is done by a simultaneous contraction of all the abdominal muscles, which both pull down the ribs and force up the abdominal viscera against the diaphragm; and the descent of the ribs is farther aided by the contraction of those muscles which arise from the sacrum and vertebræ of the loins, and are partly inserted into the lower ribs.

The movements of inspiration and expiration take place, in the healthy state, about once for every four pulsations of the heart, and therefore, on an average, about eighteen times in the minute. They are variously modified, both at the command of the will, and in obedience to certain sensations and emotions, in the performance of different complex movements to be mentioned afterwards.

As the chief agents in ordinary inspiration are the diaphragm and intercostal muscles, so the Nerves chiefly employed in conveying the stimulus given by the sensation in the lungs, must be expected to be the phrenic (which arise chiefly from the third and fourth cervical nerves, and descend along the fore part of the chest) and the dorsal nerves. As the sternomastoid muscle assists in elevating the whole chest, the trapezius in fixing the shoulders, and the serratus magnus in drawing the ribs towards the scapulæ, it must be expected that nerves supplying these muscles will be concerned. As the glottis is held open by the

crico-arytenoid and thyro-arytenoid muscle, it must be expected that the recurrent nerves of the eighth pair, which supply these muscles, will be concerned ; and, as the levatores labii superioris dilate the nostrils, it must be expected that some of the fibres of the portio dura, which supplies these, will be concerned. Accordingly, it has appeared in many experiments and observations by GALEN*, by CRUICKSHANKS †, by LEGALLOIS, by BELL, by MAGENDIE, and others, 1. That section of the phrenic nerve stops the actions of the diaphragm in inspiration ; 2. That section of the spinal cord in the lower part of the neck stops the actions of the intercostal muscles ; 3. That section of the spinal accessory nerve stops those of the sterno-mastoid and trapezius ; 4. That integrity of the nerve called external respiratory, which has similar origins to the phrenic, and supplies the serratus magnus, enables the actions of that muscle to go on, after the spinal cord has been divided in the neck ; 5. That section of the recurrent nerves, or of the par vagum above their origin, prevents the free opening of the glottis ; and, 6. That section of the portio dura prevents the dilatation of the nostrils. The necessary agency of certain nerves supplying the other muscles concerned, *c. g.* the scaleni, lesser pectoral, levator and circumflexus palati, digastric, and genio-hyoid, &c. may be safely inferred.

Experiments on animals, and cases of injury or disease in the human body, have also very frequently

* See HALLER, Elem. t. iii. p. 240.

† Phil. Trans. 1795.

shown, that division of the dorsal portion of the spinal cord renders the movement of expiration feeble and ineffectual for many purposes to which it is commonly applied.

Both by experiments on animals, of the class Mammalia, and by cases of injury of the human body, it has been ascertained, that division of the spinal cord above the origin of the phrenic nerves, palsies all the respiratory movements of the chest, and so causes sudden death. In birds, where the muscles corresponding to the diaphragm are of little avail, and respiration is entirely dependent on motion of the ribs, destruction of the dorsal portion of the spinal cord is fatal as quickly, and in the same way. In fishes, on the other hand, where the organs moving the gills have all their nerves from the medulla oblongata, the injury which palsies their respiratory movements must be as high as that part of the nervous system *. But there is no injury, except that of the origin of the eighth pair, which instantly, and in all animals, palsies the whole combination of respiratory motions; no doubt because there is no other, which puts an end to the sensation which is the common cause of them all.

It is supposed by Mr BELL, that the nervous fibres, which excite the different respiratory muscles in obedience to the sensations of the lungs, are distinct from those which move the muscles in obedience to the will; and that they excite and combine the respiratory movements, because they originate exclusively in the

* FLOURENS, in *Annales d'Histoire Naturelle*, t. xiii.

lateral columns of the spinal cord, from which the great sentient nerve of the lungs (viz. the eighth pair) also arises. But the proof of these points is essentially defective; and it will afterwards appear, that the circumstance of two nerves having any such peculiar bond of connexion at their root, if it were proved, would furnish no adequate explanation of their acting in concert with, or in obedience to, one another.

We do not, therefore, pretend to explain why the sensation caused by the venous blood in the lungs, should always excite that extensive combination of muscular movements only, by which it can be appeased; but it is obvious, as Mr BELL observes, that in Man, as in other animals, where the provisions for the reception of air are partly dependent on the nervous system, the nerves and muscles employed for this purpose are “put under the guidance of a Sensibility, more certain and more powerful in its effects than the Will.”

The lungs, in the living and adult state, having air in contact with their inner surface only, are always distended somewhat beyond the dimensions which they assume when the pressure of the atmosphere is allowed to act on their outer surface also, as by puncturing the chest. When the chest is enlarged, the air which they contain is rarefied, fresh air enters by the trachea, by reason of its own gravity and elasticity, and the lungs are farther expanded. This expansion, when the motion of the diaphragm is

free, is chiefly in the longitudinal direction; so that the lungs slide on the pleura costalis.

When the access of air to the interior of the lungs, or of part of the lungs, is prevented, either by closure of the glottis, obstruction of one of the bronchiæ, or occlusion of part of the air-cells, although the usual effort be made, the movement of inspiration is wholly or partially prevented; not because the air within the chest is a cause of that movement, but because the pressure of the air without the chest is an effectual obstacle to the movement, when no air is admitted into the interior to counterbalance it.

The passage of the air through the bronchiæ, and into the cells of the lungs, causes a gentle murmur, perceptible on applying the ear to any part of the chest where it is going on, but which is not perceived when the subjacent portion of lungs is impervious to air; and is easily altered by disease either of the substance of the lungs, or of the bronchiæ of the part, especially by morbid effusions.

The reasons which have led several physiologists to think that the lungs are not merely passive in the acts of Respiration, are—*1st*, That after the chest has been fully opened, and all motion of the lungs on the principle of suction necessarily prevented, movements in them corresponding to the respiratory efforts have still been seen in living animals*. *2dly*, That the respiratory murmur is in some individuals observed to be subject to sudden changes, for which no causes appear so probable as partial vital contractions of the

* WILLIAMS in Edin. Med. and Surg. Journal, vol. xix. p. 353.

cells of the lungs, or smallest bronchiæ*. But if any action of this kind in the lungs themselves does accompany the respiratory movements of the parietes of the chest, it must be to a very small extent only, because exposure of the surface of the lungs to the atmosphere very speedily causes death by suffocation, *i. e.* by stopping the admission of air to the lungs.

From the experiments of JURINE, MENZIES, THOMSON, GORDON, and others, it appears that the average bulk of air entering the lungs at each ordinary inspiration of a healthy man is about 40 cubic inches; and if there be 20 such inspirations in a minute, this gives 1,152,000 cubic inches of air, or about $666\frac{1}{2}$ cubic feet, drawn into the lungs in a day. It appears also, that not more than one-eighth part of the air contained in the lungs is changed by each respiratory act, not less than 280 cubic inches probably remaining in the lungs at the end of each ordinary expiration.

II. The results of very numerous experiments on the changes effected on the Air by Respiration may be stated thus:

1. It appears from the experiments of EDWARDS and others, that a slight and variable diminution of the whole bulk of the air in which an animal breathes, even in ordinary circumstances, generally takes place. When the air becomes vitiated, and the breathing difficult, this diminution is greater, probably because the lungs, in these circumstances, are not completely

* LAENNEC, *Traité d'Auscultation*, &c. tom. i. p. 188.

emptied. The proportion of oxygen in air that has been breathed is ascertained, and compared with the ordinary proportion, by different eudiometers; and the proportion of carbonic acid by exposing the air, over mercury, in a graduated tube, to aqua potassæ, which absorbs the acid.

2. The proportion of azote, in air that has been breathed, has appeared in many experiments to be the same as in the atmosphere in general, and therefore it has been supposed that this gas is neither absorbed nor exhaled at the lungs; but Dr EDWARDS' experiments, coinciding with those of several other physiologists, have shewn, that, on some occasions, there is a small increase, and on others a small diminution, of the azote of the air breathed*; and experiments made by ALLEN and PEPYS have shewn, that when oxygen, or a mixture of oxygen and hydrogen, is breathed, azote appears in the expired air; and these points being established, it becomes highly probable that there is always a certain degree, both of exhalation and absorption, of azote. In experiments made recently by DESPRETZ and by COLLARD DE MARTIGNY, a pretty uniform exhalation of azote was observed†. In the respiration of fishes, it appears, from the experiments of HUMBOLDT and PROVENÇAL, that there is, more generally, a considerable absorption of azote‡.

3. The proportion of carbonic acid in air that has been once breathed, has been found to vary from

* De l'Influence des Agens Physiques sur la Vie, p.420, *et seq.*

† Journal de Physiologie, tom. iv. et x.

‡ Mem. d'Arcueil, tom. ii.

3 per cent. to nearly 10 per cent.; but in ordinary respiration does not appear to exceed 3·5 per cent. The whole average quantity of carbonic acid given off in 24 hours, by the respiration of an ordinary sized man, appears to be about 40,000 cubic inches, which weigh nearly 3 lb., and contain about 11 ounces of carbon. The quantity of water exhaled from the lungs in 24 hours has been estimated by Dr THOMSON at 19 ounces, and by Mr DALTON at 24*. If these estimates be correct, as they greatly exceed the whole daily loss of weight attributed to this function (see p. 124), they indicate a considerable and habitual amount of absorption at the lungs.

4. It appears from the experiments of Dr PROUT, Dr FYFE, and Dr EDWARDS, that the quantity of carbonic acid thrown off from the lungs varies considerably from various causes, that it is greatest about mid-day, least about midnight, greater in middle age than in youth; that it is diminished by fatigue, by various weakening causes, and, at least in animals that do not hibernate, by external warmth.

5. Before the inquiries of Mr ELLIS, and of ALLEN and PEPYS, the most general result of experiments shewed, that the volume of carbonic acid that appears in air that has been breathed, is in general one-fifth or one-sixth less than the volume of oxygen that is found to have disappeared from it in the process†. The experiments of these last authors (chiefly confined to the human species) were thought sufficient

* See BOSTOCK'S Physiology, vol. ii. p. 111.

† ELLIS, Inquiry into the Changes induced on Atmospheric Air, &c. § 122.

to prove that the carbonic acid of expired air exactly equals in volume the oxygen that disappears; but the numerous and more diversified experiments of Dr EDWARDS and of DULONG have again led to the belief, that in the ordinary respiration of all animals, the volume of oxygen consumed is greater than the volume of carbonic acid that appears, although the amount of the difference is very variable and often slight *.

It is known that the volume of any given quantity of carbonic acid is just the same as that of the oxygen which it contains; and therefore, when it was generally believed that the carbonic acid of the expired air exactly equalled in volume the oxygen that disappeared, it appeared highly probable that the carbonic acid is formed by the union of its parts in the cells of the lungs, and that the chief office of the lungs is simply to excrete carbon, in a state admitting of its solution in the oxygen of the air. But now that it seems well ascertained, that more oxygen disappears than the carbonic acid that shews itself can account for, it becomes more probable that the carbonic acid is exhaled, as well as the water, ready formed, and that the oxygen that disappears is absorbed into the blood.

It is no sufficient objection to this opinion that a membrane intervenes between the air and the blood at the lungs, because, in various other instances, absorption of gases certainly occurs in the living body; and besides, the reddening of blood, and evolution of carbonic acid from it, take place from the action of

* EDWARDS, p. 410, *et seq.*, and Journal de Physiologie, t. iv.

air on it out of the body, and through a bladder ; and although it is true that part of the carbonic acid appearing in that case may come from the bladder, yet it has been proved, that the quantity of carbon that escapes in that experiment is greater than the loss of weight of the bladder *.

The opinion, that the carbonic acid of expired air comes directly from the blood, and that the oxygen that disappears directly enters the blood, is strongly supported, not only by the inequality of volume between the oxygen that vanishes and the carbonic acid that is evolved, but also by the following facts.

1. Experiments and observations by Dr DAVY † and others shew, that when mixed gases are confined over different membranes in the living body, oxygen disappears more rapidly than the others, and in greater quantity than the carbonic acid subsequently found can explain.

2. In experiments by COUTANCEAU and NYSTEN ‡ it appeared, that carbonic acid, in fully the usual quantity, may be exhaled from the human lungs, when the air taken into the lungs is, as nearly as possible, pure azote.

3. In many experiments by Dr EDWARDS, confirming more partial experiments of SPALLANZANI, it appeared that different animals which can exist for various periods of time in pure hydrogen, throw off

* C. WILLIAMS in *Edinburgh Medico-Chirurgical Transactions*, vol. ii.

† *Philosophical Transactions*, 1823.

‡ COUTANCEAU, *Revision de Doctrines Physiologiques*, &c.

from their lungs, when confined in such an atmosphere, nearly as much carbonic acid as when breathing in atmospheric air, and more than can possibly have existed in a gaseous form, in their lungs at the commencement of the experiments*. And a similar result was obtained by COLLARD de MARTIGNY, from experiments on animals confined in azote †.

These statements are nearly decisive; yet there is one possible source of fallacy attending them, viz. that the carbonic acid which appeared in them, instead of being exhaled from the blood, may have been previously condensed in the cells in the lungs, in the manner in which various gases are known to become condensed in the pores of charcoal ‡. And if carbonic acid exist at all times in venous blood, it is difficult to understand why it should not be at any time extricated from it by the air pump, and why the soda of the serum should not appear saturated with it.

We cannot therefore decide with absolute certainty whether the carbonic acid of expired air comes directly from the blood, or is formed in the cells of the lungs; but it appears well ascertained that a part at least of the oxygen that disappears from the inspired air is directly absorbed into the blood.

III. In order to have a precise knowledge as to the purpose served by respiration in the animal economy, it is necessary to attend to the successive steps of the

* De l'Influence, &c. p. 442, *et seq.*

† Journal de Physiologie, t. x.

‡ ELLIS, Farther Inquiries, § 611.

process by which life is extinguished,—not when an animal is confined in a limited quantity of air, and therefore soon breathes an atmosphere loaded with carbonic acid, which is a poison, but when the access of air to the lungs is in any way simply prevented; *i. e.* the process of death by Asphyxia, or beginning at the lungs.

The experiments of BICHAT, BRODIE, and others, have satisfactorily shewn, that a quantity of the blood sent from the right side of the heart to the lungs, although not arterialized there, passes on to the left side of the heart, and is propelled into the arteries; and that *as soon as this venous blood reaches the brain, the animal becomes insensible, and generally convulsed* *. But the circulation of venous blood becomes gradually weaker, and, in warm-blooded animals, ceases after a very few minutes; not, however, as BICHAT supposed, because the venous blood has penetrated the muscular substance of the heart, and destroyed its vital power, but because the *venous blood has failed to penetrate the substance of the lungs*, and is no longer delivered to the left side of the heart in sufficient quantity to maintain the circulation †.

Accordingly, immediately after death from this cause, the blood is found accumulated in large quantity, not in the left side of the heart and aorta, but in the lungs, right side of the heart and great veins, indicating that the stop to the circulation had been in the lungs. And for some minutes after the circu-

* BICHAT, *Recherches Physiologiques*, Art. 7.

† See KAY's *Experiments on Asphyxia*, *Edinburgh Medical and Surgical Journal*, vol. xxix. pp. 42, 46.

lation has ceased in a warm-blooded animal, it is still possible to restore it by blowing air into the lungs, which would not have been the case if the cause of the failure of circulation had lain at the heart*.

Venous blood, penetrating the substance of muscles, appears from the experiments of Dr KAY, and from some of those of Dr EDWARDS†, to support their irritability in some degree, although less effectually than arterial blood.

It appears from these facts, that in death by asphyxia, the deleterious influence of venous blood is exerted first on the nervous system; next, and most fatally, on the circulation in the capillaries of the lungs (as was already remarked, p. 43), and, in a less degree only, on the heart, or other muscular parts. Both the animal and organic life are thus dependent on the arterialization of the blood, which penetrates the textures concerned in them; but the dependence of animal life on this process is more immediate, perhaps simply because the nervous system is a more delicate texture, and the changes which take place in it more easily arrested by any noxious influence. The lungs suffer more than the heart, perhaps merely because every part of their structure is more completely penetrated by, and exposed to the influence of, the venous blood.

In these ways, venous blood admitted into the ar-

* See ROESLER, in *Edinburgh Medical and Surgical Journal*, vol. xxiii.; & GOODWYN'S *Answer to BICHAT*, ditto, vol. xxxiv.

† *De l'Influence, &c.* Part. i. Chap. i., and Part. iv. Chap. iv.

terial system, is more injurious than the simple failure of the circulation, as appears from what is observed in the human body, in some cases of very profound syncope, but in a much greater degree in hybernating animals;—where an almost total suspension both of circulation and respiration can be borne with impunity, much longer than the privation of air can, when the circulation is vigorous.

The experiments of CRUICKSHANKS*, BICHAT, BRODIE, and others, shew farther that in what is properly called death by Coma, or beginning at the brain, where the primary change is gradually increasing insensibility, the circulation survives the respiration, and comes to a stand in the same way as now described, and from the same noxious influence of venous blood. This is indeed sufficiently proved by the effect of artificial respiration,—often practised on animals since the time of FONTANA,—in maintaining the circulation, long after it would otherwise have ceased, when the functions of the brain have been suspended, or when the head has been cut off. But the blood becomes venous in the case of death by coma, not because the air cannot enter the lungs, but because the sensation which prompts to the act of respiration is extinguished, and the lungs are not expanded to receive it. In the one case, the sensibility fails because the blood has become venous; in the other, the blood becomes venous because the sensibility has failed. The Organic Life is extinguished in the same way in both cases, viz. by the circulation of venous

* Philosophical Transactions, 1795.

blood ; but the extinction of Animal Life is, in the one case the consequence, and in the other the cause, of the failure of respiration *.

In the case of approaching death by coma, from an injurious influence acting primarily on the nervous system, the blood may therefore be arterialized, and kept in motion for a time, by artificial respiration, after the natural respiration has ceased ; and, if the cause which has extinguished sensibility has been only temporary, the organic life may in this way be maintained, until the effect of that cause on the nervous system, and on the animal life, has gone off, and the natural mode of breathing been resumed ;—as has been shown by the recovery, thus effected, of animals under the influence of narcotic poisons, by Mr BRODIE †, and in one case of apparent death by opium, in the human body, by Mr WHATELY.

It appears from the experiments of Mr BROUGHTON ||, that when pure oxygen is breathed so long that the blood is arterial even in the veins, the nervous system is affected as by a narcotic poison, and death takes place by coma in the way now described ; so that the effect of an excess of oxygen absorbed into the blood, upon the brain, is very similar to that of carbonic acid ; and a certain dilution of oxygen by azote is necessary to qualify it for producing that change on the blood, which enables it to maintain the vital action of the nervous system.

* See BICHAT, *Recherches*, &c. Art. 10.

† *Phil. Trans.* 1812.

‡ *London Medical Observations and Inquiries*, vol. vi.

|| *Quarterly Journal of Science*, April 1830.

SECTION X.

OF ANIMAL HEAT.

It is evident that one of the changes continually in operation, in living animals, is an evolution or disengagement of caloric, whereby their temperature is generally kept above that of the surrounding media, and the effect of which is much aided, in many animals, by the nature of their coverings, and by the thickness of the adipose texture beneath them.

As the formation of carbonic acid, by union of its constituents, is a process which is attended with evolution of heat in all other circumstances where it occurs, and as the ordinary temperature of different classes of animals appears strictly proportioned to the amount of oxygen which they consume, and of carbonic acid which they exhale, it has generally been supposed, since the time of Dr BLACK, that the union of carbon and oxygen to form the carbonic acid of the expired air, is at least a great source of the heat of animals.

This is strongly supported by the fact, that animals in a state of winter torpor, or in a state resembling that, when their respiration and circulation are slow and feeble, and their temperature very low, may be roused by exciting sensations,—even by the sudden application of intense cold,—and in proportion as their

respiration becomes more frequent and fuller, and their circulation stronger, their temperature rises, often by many degrees, while that of the surrounding air is unchanged or even lowered *.

Farther, some of the observations made on the temperature of animals, in which the circulation has been maintained, after apparent death, by artificial respiration, seem to leave no room for doubt as to the influence of this cause on animal heat; because they show that when the insufflation of cold air into the lungs is not too frequently repeated, and is successful in maintaining the circulation, it may materially retard, instead of accelerating, the cooling of the animal †.

But there is a difficulty in understanding how a cause which appears limited to one organ, should produce the elevation of temperature which is general over the body: For, although it appears from the observations of Dr DAVY, and others, that the temperature of arterial blood in the chest, is about 1° higher than that of venous; and that the temperature of the chest is generally several degrees higher than that of the extremities; yet this difference is certainly not so great as would be found, if the only calorific change were at the lungs, and the rest of the body were only warmed by the superior temperature of the arterial blood flowing thence.

* See EDWARDS, De l'Influence, &c. Part iv. Chap. 10.

† See particularly Experiments by Dr HASTINGS, in Dr WILSON PHILIP'S Experimental Inquiry, p. 223; by Dr HALES, in London Medical and Surgical Journal, 1814; and by Dr C. WILLIAMS, in Edinburgh Medico-Chirurgical Trans. vol. ii.

But it is to be observed here,

1. That if, as appears most probable from the facts already stated, the carbonic acid that is exhaled from the lungs is not formed there, but, chiefly at least, throughout the capillaries of the system, the evolution of heat from this source must be expected to take place generally over the body, wherever the arterial blood becomes venous.

2. That even although the whole calorific change be at the lungs, if, as Dr CRAWFORD endeavoured to show, arterial blood has a greater specific caloric than venous, the blood which becomes arterial at the lungs will necessarily absorb the greater part of the caloric evolved by the change on the air there, and only set free this caloric in the capillaries of the system, where it becomes venous again. And although Dr DAVY's estimate of the difference of specific caloric, and arterial and venous blood, is much less than Dr CRAWFORD's, yet even he has assigned a higher specific caloric to arterial blood; and no great reliance can be placed on any estimate of the exact difference.

But although there appear sufficient grounds for believing, that the formation of the carbonic acid which is exhaled at the lungs, is one essential element in the process by which the heat of animals is maintained, yet it is very doubtful whether this is a sufficient cause, for the whole caloric which is evolved in their bodies. The experiments of DULONG and of DESPRETZ, made by enclosing a small animal in a box placed in water, measuring and analyzing the air which it inspired and that which it expired, observing

the elevation of the temperature of the water which corresponded to the evolution of a given quantity of carbonic acid from its lungs, and comparing this with the estimate, obtained in a nearly similar way by LAVOISIER, of the quantity of caloric evolved by the combustion of a given quantity of carbon,—lead to this result, that the quantity of carbonic acid thrown off in a given time from an animal, is sufficient to account for nearly three-fourths of the caloric which the animal evolves (from 47 to 75 per cent.), but not for the whole of that caloric *.

It is highly probable, that *several* of the chemical changes which are wrought on the blood, during the greater circulation, are attended with an evolution of caloric †; and that the application of oxygen to the blood, in respiration, is essential to the animal heat, not simply by combining with carbon, and so generating heat, but by adapting the blood for the maintenance of the *various processes* (partly chemical and partly vital), by which it is to be changed in the living body; and of which one of the results is, the formation of the carbonic acid which appears in the expired air.

The temperature of the body is not raised by voluntarily increasing or quickening the acts of respiration; but it is raised by voluntary exertions of other muscles, which accelerate the circulation; and so necessitate an increased frequency of respiration; and this

* Journal de Physiologie, t. iii. & iv.

† See C. WILLIAMS, Edin. Medico-Chirurg. Trans. vol. ii.

appears to indicate, that it is dependent, not simply on the application of oxygen to the blood, but on the changes which take place during circulation, and to the maintenance of which, the oxygenation of the blood is one essential condition.

The evolution of heat in the animal body has been found, in the experiments of Mr BRODIE and others, as well as in numerous cases of disease in the human body, recorded by Mr EARLE and others, to be much influenced by injuries of the nervous system, being generally diminished in those animals, or in those parts of the human body, in which the chief functions of the nervous system have been lowered or suspended; but, in a few cases, being increased in consequence of such injuries. But as we know that the circulation, and especially the circulation in the capillaries, and that secretion and nutrition, are easily and variously affected by injuries of the nervous system, we can readily understand this farther influence of such injuries; without being obliged to suppose that any influence derived from the brain or nerves is essential to animal heat, or that chemical principles are inadequate to explain it. Accordingly, in numerous experiments by CHOSSAT, it appeared, as a general result, that the injuries of the nervous system, which lower the temperature of animals, are the same which manifestly diminish the processes of secretion and nutrition *.

* *Memoire sur l'Influence du Systeme Nerveux sur la Chaleur Animale.*

IN MR BRODIE'S experiments, after the head of an animal was cut off, and the circulation maintained by artificial respiration, repeated at least as frequently as the natural breathing of the animal, the cooling of the animal was accelerated, although the usual quantity of carbonic was thrown off for some time. But, according to the most probable opinion, already stated, as to the source of the carbonic acid of expired air, what was thus thrown off had been formed previously, and the changes leading to the formation of fresh carbonic acid were suppressed by the injury.

It is necessary to distinguish carefully between the power of generating heat in the animal body, and the power of bearing cold. The former appears to be a chemical effect of the changes which take place on the blood in the living body, and is directly proportioned, so far as observations have gone, to the vigour with which the Circulation and Respiration, or the analogous functions in lower animals, are performed. It is greatest and most enduring at the age of greatest strength, and during winter, in those animals which preserve their strength and activity in that season,—the velocity of their circulation and their consumption of air being at the same time augmented. The latter appears to be an original endowment of the living solids, varying in different kinds of animals, and in different states of the same; and is greatest in cold-blooded animals,—in animals that hibernate during their state of torpor,—and in the young of warm-blooded animals; *i. e.* in cases where the circulation is languid, or easily depressed: it varies therefore

nearly in the inverse ratio of the power of generating heat *.

Animals possess the power of maintaining their own temperature, not only when that of the surrounding air is lower, but also when it is higher than themselves ; and in the experiments of Sir C. BLAGDEN, DE LA ROCHE, and others, a temperature approaching to, or even exceeding, that of boiling water, has been borne by the human body, for many minutes, without more elevation of the temperature of the skin than 4° of Fahrenheit. The experiments of DE LA ROCHE and BERGER † have shewn that a lower temperature than that of the air is in like manner maintained by moist and very porous substances, although not endowed with life ; and again, that when hot air is saturated with humidity, so as to allow of no evaporation, the temperature of animals confined in it is raised, and they are soon killed. This power of resisting the influence of high temperatures seems therefore to be owing entirely to the increase of evaporation from the surface, and the cooling effect of that process.

* See EDWARDS, de l'Influence, &c., Part I. Chap. II.; Part III. Chap. I., II., III., VI.; and Part IV. Chap. VII.

† Journal de Physique, tom. lxiii. lxxi. lxxvii.

SECTION XI.

OF DIGESTION.

THE processes of Nutrition and of Excretion, already considered, manifestly require, in the human body as in all living beings, that the nourishing fluid should not only be regularly purified by exposure to air, but also receive frequent supplies both of solid and fluid materials, to compensate for the continual losses which it undergoes.

For the nourishment, probably of all animals, certainly of all of the higher classes, and even for the greater part of the nourishment of vegetables, at least under the present constitution of the atmosphere*, it is necessary that much of the materials taken into the system should have been previously organized. As the life of animals springs only from the life of others of their own species, so it is maintained only by the life of other organized beings.

It is further necessary, probably in all living beings, that the nourishment, received from without, should be acted on by the fluids of the body into which it has been taken, should be reduced, by their means, and by water from without, to a fluid form, and so

* See p. 175.

far assimilated to them, before it is applied to the purposes to which it is destined.

All these objects are accomplished in vegetables, and perhaps in the lowest order of animals, without the appropriation of any particular organs to the reception of unassimilated nourishment, and without the aid of any appetites or other mental acts. The circumstance, in the life of animals, which appears especially to require a separate apparatus for the occasional reception and gradual assimilation of food, is their faculty of Locomotion, which precludes the possibility of their continual adaptation to the reception of solids and fluids from without, and makes it necessary that they should carry about with them, and gradually avail themselves of, the materials by which they are to be nourished. This condition in the economy of animals, therefore, imposes the necessity of the function of Digestion, as subsidiary to that of Nutrition *.

In all animals, the first part of the vital actions by which these objects are accomplished, is put under the guidance of Sensations ; but as the solids and fluids, which are the subjects of digestion, are not always within the reach of animals, the muscular actions, by which these sensations are to be appeased, are not made directly consequent on their being felt (as is the case with the movements of respiration), but are linked with the sensations by the more complex mental processes to which we give the names of Appetites and Instinctive propensities. And as it is

* See CUVIER, Leçon 16.

dependent on these different mental acts, so this function differs from all those which we have yet particularly considered, in this important circumstance, that wherever it exists it is fitted and intended to be a *source of enjoyment*.

As the materials on which this function is to be performed are numerous and diversified, and the circumstances of the animals that perform it very different, so we observe great varieties, both in the mental and physical part of the process, in the different orders of animals. Without altering the general plan of the function, or even the essential parts of the organs concerned in it, Nature makes such additional provisions, in the instincts by which the reception of food is guided, and in the organs by which it is assimilated, as are suited to the circumstances in which each animal is placed, to the food on which it is to subsist, and to the ulterior purposes which it is to serve in the world.

For example, the agility, ferocity, and predatory instincts, and the canine teeth, high zygomatic arches, and strong temporal muscles of the carnivorous quadrupeds, with their short and simple alimentary canals, fit them for subsisting on prey which it is difficult to procure, and to prepare for introduction into the stomach, but which requires no great chemical change to be wrought on it there, that it may be assimilated to the animal textures; while the quiet habits, the comparatively feeble limbs, and large bodies, the ruminating instinct, the deficiency of canine and incisor teeth, the complex stomachs, and long intestines of the ruminating animals, fit them for

obtaining the greatest quantity of nourishment from vegetable matters, which they can easily procure, and easily reduce to the proper consistence for entering the stomach and bowels; but which must necessarily undergo much change there, before they can be applied to the nutrition of animals. Again, the camel and lama, which traverse the deserts, are instinctively led to swallow large quantities of water beyond what the purposes of their digestion and nutrition immediately require; and their first and second stomachs are provided with numerous cells, with muscular orifices, in which it is securely stored, until it is required to assuage thirst, or to assist the assimilation of food. And graminivorous birds, instead of having heavy jaws and teeth, for the requisite comminution of their food, are prompted by instinct to swallow gravel, and furnished with stomachs of extraordinary muscular strength, the action of which, aided by the attrition of the gravel, is effectual for the purpose.

The mental powers and inclinations, which lead the whole human race to practise the art of cookery, are equally a part of the plan of Nature, for the management of this function in our species, as any of the instincts of animals; and enable us to dispense with additional provisions, in the structure of the digestive organs, which would otherwise be necessary to secure the digestion of many articles of our diet.

The different actions, however, which immediately precede the reception of food and drink into the stomach, even in our species, are truly *instinctive*; that is, they are excited by mental determinations, which

are linked to certain complex sensations,—to a combination of the simple feelings of hunger and thirst, with those which result from the sensible qualities, especially the taste and smell, of the objects by which hunger and thirst are to be allayed ; and although very complex, they require no experience or education.

Hunger and Thirst, in the natural state, are sensations probably dependent on the nerves of the stomach almost exclusively ; for although thirst is naturally referred to the mouth and fauces, it has been found, in cases where a preternatural opening has been made into the œsophagus from the neck, not to be relieved by any applications to the upper portion of the divided œsophagus, although quickly relieved in the usual way by drink taken into the stomach. They are not destroyed, but manifestly perverted, by section of the eighth pair of nerves. Thirst would seem to depend simply on want of the usual moisture on the mucous membrane, and is relieved by whatever is effectual in restoring the natural condition as to moisture. Hunger is certainly not dependent on the action of the solvent liquor of the stomach, already effused on the mucous membrane, because it is instantly destroyed by mental emotions, which cannot remove such a liquor ; and besides, we shall see reason to think, that the solvent liquor does not usually exist in the stomach, at the time when hunger is most felt. It is probably connected with a particular state of the contraction of the muscular fibres of the stomach ; but, according to the observa-

tions of MAGENDIE, at the time when it is most felt, the stomach is not strongly contracted in itself.

Whatever be the conditions under which the nerves of the stomach become the seat of these sensations, it is certain that, in the healthy state, they are a true index, not only to the state of the stomach, but to the immediate wants of the system at large.

The sensations excited by the smell, taste, or touch in the mouth, of alimentary substances, are naturally either agreeable or disagreeable, especially when hunger or thirst co-exist with them; but these feelings are susceptible of much alteration by custom and habit. These complex sensations, and accompanying mental emotions, produce two well-marked effects,—an increased flow of the secretions of the mouth and salivary glands,—and certain definite instinctive muscular contractions; and the different varieties of these sensations prompt to corresponding variations of the muscular actions that succeed them. It is because they give occasion to these instinctive muscular contractions, that these sensations are called *Appetites*. These actions, however, are always distinguished from those which depend on sensation simply, by this circumstance, that they are felt in ourselves, and inferred from observation in other animals, to be completely under the control of the will, even when the sensations, which prompt to them, are felt the most keenly. There is a propensity leading directly to the performance of a certain definite action, on each of these complex sensations being felt; but the particular mental act,

called a Volition, always intervenes between the sensation felt, and the muscular action excited.

In this way, the contact of liquids with the lips excites, and the reception of liquids into the mouth is much promoted by, the instinctive but complex act of Suction, in which, by partially closing the lips, and at the same time, by either moving the tongue backwards and forwards after the manner of a piston, or by acts of inspiration, or by these two movements together,—we cause the pressure of the atmosphere to urge fluids into the mouth.

The contact, especially of solid food, with the interior of the mouth, excites also the act of Mastication, performed by alternating contractions of the muscles, which pull the lower jaw upwards towards the bones of the head and face, and downwards towards the os hyoides and sternum,—the jaw moving on its condyles as a lever of the second order, and subjecting the food to the pressure of the teeth.

The increased flow of the saliva and mucus by the mouth is unconnected with any act of instinct or volition, which never affects any secreting organs; but results directly from the complex mental feeling above described, and may be reproduced by the emotion, which forms a part of that feeling, even when that is excited by recollection, independently of any physical impression on the parts.

The experiments of Mr BELL and Mr MAYO are quite satisfactory as to the dependence of the sensations of the lips and mouth on the ganglionic portion of the fifth nerve;—as to the dependence of the con-

tractions of the temporal, masseter and pterygoid muscles, which elevate and close the lower jaw, on the anterior portion of the fifth, which does not pass through the Gasserian ganglion,—and as to the dependence of the motion of the lips and tongue on the portio dura and ninth nerve. The particular nerves concerned in the depression of the lower jaw by the digastric, genio-hyoid, and mylo-hyoid muscles, &c. have not been so clearly demonstrated.

We can have no doubt, that the increased flow of the saliva and mucus, consequent on the sensations and emotions described, is effected through the nerves of the salivary glands and mucous glands and membrane; and these are chiefly the ganglionic portion of the fifth, and branches of the eighth pair and sympathetics; but the influence of these nerves on the secretions has not been distinctly elucidated by experiment.

The food, comminuted and moistened in the mouth by the means now mentioned, is prepared for the act of Deglutition, the first and most complicated part of which is also guided by an instinctive impulse. The food is first pushed back by the tongue, till it arrives within the sphere of action of the constrictor muscles of the pharynx; but at the same time that it is moved downwards by the successive contractions of their fibres, several other movements take place. 1. The passage of the fauces is narrowed by the contraction of the *Constrictores Isthmi Faucium*, in the anterior arches of the palate. 2. The *Velum Pendulum Palati* is raised and stretched by the *Levator*

and *Circumflexus Palati*, so as to direct the food past the opening of the posterior nares. 3. The glottis is closed, partly by depression of the epiglottis, but chiefly by apposition of the arytenoid cartilages. 4. The larynx, and lower portions of the pharynx, attached to it, are drawn *upwards*, partly by the muscles connecting the larynx to the os hyoides and lower jaw, but more especially by the lowest of the constrictors, and by the *Stylo-pharyngeus* and *Palato-pharyngeus*; the moveable origin of the latter muscle in the *velum pendulum* being fixed at the time. By this combination of movements, the food or drink is rapidly and safely carried past the openings to the nares and lungs, and lodged on the lower part of the pharynx, after which its descent is slow.

Great part of this movement is distinctly voluntary; though prompted by instinct only; but the actions of the constrictor muscles of the pharynx in it appear to be strictly dependent on the sensation caused by the matter to be swallowed, when it touches the mucous membrane of the pharynx, because they cannot be correctly imitated by any voluntary effort, when there is no substance to be swallowed. The ninth and *glossopharyngeus* nerves are no doubt much concerned in this action, but the precise office of each nerve in these parts has not been ascertained.

In passing from the Pharynx to the *Œsophagus*, the food enters the confines of *Organic Life*, and its subsequent movements are neither excited by the will, nor attended by the consciousness of the individual. The essential parts of the whole canal through which

it now passes are, the mucous membrane on which it moves, and the muscular coat, provided both with longitudinal and circular fibres, by which it is propelled, but which is much thicker and stronger in the œsophagus than in the stomach or intestines; and to these, in the abdomen, the serous coat is added.

The muscular action propelling the food is of the same general description in all parts of the canal,—each portion of the canal contracting as the food distends it, and continuing contracted until the portion next in advance has contracted also; but the rapidity of the motion is very various in different parts, and at different times. The lower part of the œsophagus exhibits, when exposed, continued gentle movements of contraction and relaxation, (perhaps the effects of sensation), dependent on the eighth pair of nerves, which form a plexus about the part, and ceasing on their division*; on which account, after that operation, part of the food taken ascends to the pharynx. In a slighter degree, a similar movement in the stomach appears also to be determined by these nerves†. But no such effect results from division of any nerves on the peristaltic movements of the intestines.

When the stomach receives the food, its great left sac is chiefly distended, its surfaces rounded, and its great arch thrown forward; and in this position it retains the food for a time, which is very various in different cases, letting successive portions escape

* MAGENDIE, *Precis*, &c.

† BRESCHET and EDWARDS in *Arch. de Med.* 1825, and TIEDEMANN and GMELIN, *Recherches sur la Digestion*, sect. iii. p. 374.

by the pylorus, after they have undergone certain changes; which do not begin immediately after it is taken, and are not completed until several hours after an ordinary meal. The chief obstacle to the passage of undigested materials from the stomach, is the contraction of the circular fibres at the pylorus; and for this we can assign no cause but a peculiarity of the irritability of these fibres.

The sensations which prompted the reception of food and drink abate after they are received into the stomach, but not simply in consequence of its distention; probably rather in consequence of the increase and alteration of the secretion of the stomach thereby effected. They are more easily appeased by a small quantity of nutritious food, or of slightly stimulating drink, than by larger quantities of other matters. Different and more grateful sensations succeed them, which are certainly dependent on the eighth pair of nerves; because, when these are cut in the neck, the animal is not aware of the condition of his stomach, and continues to eat after that is distended with undigested food. The sensations which accompany and succeed the reception of food into the stomach, prompt to no muscular action, but are probably of importance in exciting the secretion of the stomach.

The materials on which the function of Digestion, in the human stomach, may be performed, are the chief proximate principles of animal and vegetable substances,—Fibrin, Albumen, Gelatin, Osmazome, &c., the vegetable Gluten, Starch, Gum, Extractive matter, Sugar, and animal or vegetable Oil. In regard to these the following facts demand attention.

1. They answer for the purpose of Digestion best, when in a medium state of aggregation and density; hardened or dried food, solid albumen in any form, vegetables not softened by boiling, are acted on with difficulty in the stomach; and, on the other hand, very soft or liquid aliments seem to give but little stimulus to the digestive process. Of the different proximate principles, Oil is perhaps, in any form in which it can be taken, the most difficult of digestion.

2. It has been fully ascertained by MAGENDIE, LEURET and LASSAIGNE and others, that a certain *variety* of articles, whether of vegetable or animal food, is necessary in various animals, on which experiments were made, in order that the due action of the stomach on them may take place, and that they may be effectual for the nourishment of the body; the animals that were fed on single chemical principles only becoming almost uniformly, after a time, unable to digest sufficient quantities of these for the support of life. The importance of the art of Cookery to the human species, no doubt, consists in its fulfilling these necessary conditions as to the consistence and the mixture of aliments.

3. According to Dr PROUT, all the articles of food which are used by the human species may be arranged, according to their chemical relations, under three heads, the Saccharine, the Albuminous, and the Oily; the first of which consists of carbon in different proportions (from 30 to 50 per cent.) chemically combined with water; the two last of compound bases also united with water; the carbon in some of the oils is nearly 80

per cent., and its proportion therefore varies, in the different aliments, from 30 to 80 per cent. The prototypes of these three classes of aliment exist in the milk; and of these three he thinks that a mixture of two at least must be taken, either together or soon after one another, to answer the purposes of Digestion and Nutrition.

4. There is much variety in individuals as to the kind of food that is found easy or difficult of digestion; and by repetition and habit, those kinds which are at first unsuitable, are very often found ultimately to become easy of digestion and nutritious. This is perhaps sufficiently explained by the connexion of the process with the sensations of the stomach, and by the general principle of the influence of habit on sensation.

When such food as is suitable for digestion has been received into the stomach of a warm-blooded animal, and is retained there in the usual way, the mucous membrane becomes more vascular than before, its villi prominent, and its cryptæ or minute cells appear full of their secreted fluid; and this increased flow of the secretion of the stomach is manifestly promoted by rest.

When the stomach is examined two or three hours after food has been freely taken, the portion of the alimentary mass which lies outermost, or next the mucous membrane, is found most altered, and the central part least altered; but towards the pylorus the alteration of the whole contents is more uniform; apparently because the portions of food that have been

acted on by the fluid at the surface of the mucous membrane, all round the stomach, pass gradually on to the pylorus, while fresh portions from the interior of the mass take their place on its exterior; and after being subjected to the same change, are pushed forwards in their turn *.

The change that is wrought on the food during this process is its conversion, more or less complete, into the homogeneous, greyish, pultaceous matter called Chyme.

It is satisfactorily ascertained by numerous experiments, of MONTEGRE, PROUT, MAGENDIE, TIEDEMANN and GMELIN, LEURET and LASSAIGNE, and others, made on a variety of animals, using very different kinds of food, that this chyme, in the healthy state, is uniformly, though slightly, *acid*.

Farther, the following facts leave no room for doubt, that the acidity, found in the healthy state, does not depend on fermentation of the alimentary matters, but chiefly, if not entirely, on the nature of the secretion of the stomach itself.

1. The chyme is acid from the commencement of its formation, *i. e.* long before the same substances, kept at the same temperature, can have run into acetous fermentation.

2. The secretions of the living stomach, so far from promoting putrefactive fermentation at least, are decidedly antiseptic.

3. The acid found in the chyme is, for the most part indeed, the lactic, *i. e.* a modification of the ace-

* WILSON PHILIP, Experimental Inquiry, ch. vii. sect. 1.

tous ; but in part also it is the muriatic, which of course cannot be generated by fermentation *.

4. The presence of the same acids in the stomach is determined, not only by the reception of food, but by the excitation of grains of pepper, or even of particles of sand †.

In fasting animals, it appears that this acid liquor is seldom found in the stomach, but its formation appears always to be excited, in the healthy state, by the presence of food in the stomach ; and even its quantity to be greater, in proportion as that food is more difficult of digestion, if within the limits of the natural food of the animal ‡.

This enables us to understand, that the fluid taken from the stomach of fasting animals should often have been found, as in the experiments of MONTEGRE, ineffectual in producing an *artificial digestion*, i. e. *solution* of the food, and formation of chyme, when mixed with alimentary matters at the temperature of the body ; and yet that in many experiments of REAUMUR, SPALLANZANI, STEVENS, LEURET and LASSAIGNE, &c., alimentary matters introduced into the stomach in perforated balls or tubes, should have undergone digestion, evidently from the action of a fluid in the stomach ; and that in those of TIEDEMANN and GMELIN, the acid chyme itself, beginning to form in the stomachs of animals recently fed, should

* PROUT, Philosophical Transactions, 1824 ; and Annals of Philosophy, vol. xii., TIEDEMANN and GMELIN, Recherches sur la Digestion.

† TIEDEMANN and GMELIN, Recherches, &c. sect. ii. p. 161.

‡ Ibid. sect. iii. p. 335.

have been found effectual for the artificial digestion, out of the body, of fresh aliments*.

The solvent power of the acid liquor formed in the stomach after the reception of food, is most clearly demonstrated by its having dissolved portions of the stomach itself after death, in various cases, both in the human species and in animals, where death has taken place suddenly during the act of digestion. But it is seldom, and perhaps never without disease of the secretion at the stomach, that any such solvent power is found to have been exerted where death has taken place during fasting†.

Some part of the aliment always passes the pylorus along with the chyme, unchanged; and according to the observations of LONDE‡, made on the human body, in cases of artificial anus, animal food is longest retained and most altered in the stomach, and vegetable food passes out of the stomach more rapidly, and less changed, and probably undergoes more change in the intestines.

The chyme in the stomach appears to contain little or no matter having exactly the chemical properties of albumen, unless albumen has formed part of the food taken, and therefore shews little approximation to the chemical nature of the blood§. But, according

* *Recherches, &c.* sect. iii. Exp. 30 & 31.

† See CARSWELL on the Digestion of the Coats of the Stomach after Death, in *Edinburgh Medical and Surgical Journal*, Oct. 1830; and GAIRDNER on Perforation of the Stomach, in *Edinburgh Medico-Chirurgical Transactions*, vol. i.

‡ *Archivès de Medecine*, tom. x.

§ See PROUT, in *Annals of Philosophy*, 1819; and TIEDEMANN and GMELIN, *Recherches, &c.* sect. iii. p. 344 & 388.

to the microscopical observations of LEURET and LASSAIGNE, it would seem to contain a number of globules, resembling those of the blood, and having the same tendency to arrange themselves into fibres. And in the stomachs and intestines of the cold-blooded animals, these and other authors have described a number of globular bodies, which were thought to have a power of spontaneous motion, resembling animalcules *.

The passage of the chyme out of the stomach does not take place uninterruptedly, but by successive series of peristaltic movements along the stomach and duodenum, each of which is preceded by a series of slighter movements in the opposite direction †.

After passing the pylorus, and mixing with the Bile and Pancreatic Juice, which slowly distil into the duodenum, and with the Mucus of the Intestines, the Chyme and undissolved aliments gradually separate into the Chyle, which is absorbed into the lacteals, and the feculent matter, which passes on to the large intestines; and the more watery portions of the chyme seem to be absorbed away from the rest chiefly by the veins, both of the stomach and intestines.

The peculiar matter of the bile appears manifestly to connect itself with such substances as have passed unchanged from the stomach, and to become part of the feces ‡; and is no doubt useful, by stimulating

* Recherches pour servir à l'Histoire de la Digestion.

† MAGENDIE, *Precis*.

‡ See p. 110.

both the mucous secretion and the peristaltic movements of the intestines. The free alkali of the bile and perhaps of the mucus unites with the acids of the chyme, and also with any oil which the chyme may contain; and it is probably in part from this cause that the acidity of the contents of the canal gradually disappears in the small intestines*. The white colour often seen in part of the contents of the intestines, as well as in the lacteals, appears to arise chiefly from oily articles of food uniting themselves with the alkali †.

It appears, on comparing the experiments of Mr BRODIE, Mr MAYO, MAGENDIE, LEURET and LASSAIGNE, and TIEDEMANN and GMELIN, that after the biliary ducts are tied in animals, a matter, possessing the chief properties, though not the usual white colour, of chyle, may be formed, and digestion go on to a certain degree; but cases of jaundice, without organic disease, in the human body, seem sufficiently to indicate, that digestion in these circumstances is imperfect.

As the Pancreatic Juice contains much albumen, and as it is found most abundantly in herbivorous animals, which have no albumen in their food, it is thought probable that a greater portion of it, than of the bile, goes to the formation of the chyle. It is certain, from the experiments of Dr PROUT, that albumen is found in larger proportion, and more dis-

* PROUT, TIEDEMANN and GMELIN.

† TIEDEMANN and GMELIN, MAGENDIE.

tinctly formed, in the fluid of the small intestines, during digestion, than in the stomach; that it is found still more distinctly, and in larger proportion, in the lacteals and thoracic duct; and that it is not found at all in the larger intestines. The organic globules described by LEURET and LASSAIGNE, and which are probably composed chiefly of albumen, or animal matter closely resembling it, were also seen much more abundantly in the contents of the small intestines than of the stomach.

The chyle, which is found in the lacteal vessels, certainly contains very numerous globules, similar to those in the blood, but of a white or grey colour; and the formation of these globules is, no doubt, the main object of the whole process of digestion. After passing through the mesenteric glands, and in the thoracic duct, *i. e.* when it must have been mixed with the contents of lymphatic vessels, and probably with some of the contents of arteries*, the albuminous contents of the chyle are more distinct; it contains a little fibrin, and coagulates on exposure to air, after the manner of blood, although less firmly, and is now slightly alkaline†. Its composition, in the thoracic duct of a dog, fed on animal food, is thus stated by Dr PROUT:

Water,	89·2
Fibrin,	·8
Incipient albumen,	4·7
Perfect albumen,	4·6
Salts,	·7
<hr/>	
100.	

* See p. 77.

† TIEDEMANN and GMELIN, sect. iii. p. 385.

The proportion of animal matter in the chyle from vegetable food is less.

According to TIEDEMANN and GMELIN, the acidity of the mixed fluids of the intestines, which disappears in the course of the Ileum, re-appears in the Cæcum; and as there is necessarily a considerable delay in the passage of the contents of the bowels at this point, particularly in herbivorous animals, in which the cæcum is in general more developed than in man, it is probable that some fresh chyme is formed here, and partly converted into chyle as it passes along, and is absorbed from, the great intestines.

From the experiments of MAGENDIE and CHEVREUL, it appears that oxygen and azote exist in the stomach during digestion; but that, in the lower intestines, the oxygen is found to have wholly, and the azote partly, disappeared,—and that they are replaced by carbonic acid, hydrogen, and carburetted hydrogen, with sometimes a little sulphuretted hydrogen.

It is still doubtful whether these gases have been in part secreted by the intestines; but it seems beyond doubt, that part of those which exist in the stomach must be absorbed in the bowels.

As the Chyle is mixed with the blood just before its entrance into the lungs, and is never recognized in blood that has passed through the lungs, it appears highly probable that a change takes place on it there, which completes its assimilation; and as nourishment of animal textures, of which azote is a constituent, may be effected without the use of any food known to

contain azote, and as we have seen the possibility both of absorption and exhalation of azote at the lungs, and that fishes, which have less access to air than terrestrial animals, habitually absorb a quantity of the azote of the air they breathe,—it has been naturally conjectured, that the addition of azote from the atmosphere to the blood at the lungs, is a part of the process of assimilation there; but no satisfactory evidence of such an action at the lungs has been obtained.

The examination of the course of the lacteals, in all the vertebrated animals, and the experiments of DUPUYTREN and others, in which ligature of the thoracic duct (where that was single), was followed by rapid emaciation and death, leave no room for doubt that the main course of the chyle absorbed from the intestines, is through the Thoracic Duct to the Subclavian Vein. But on the other hand, that some admixture of the contents of the lacteals with those of the bloodvessels takes place in the mesenteric glands, appears probable, from the structure of these glands, formerly described,—from the change observed in the chyle by TIEDEMANN and GMELIN, after it has passed through these glands,—from streaks of white matter, resembling chyle, having been observed, particularly by the same physiologists, in the larger mesenteric veins,—and from the result of two experiments of LEURET and LASSAIGNE, in one of which a dog recovered after ligature of the thoracic duct, and no auxiliary duct could be discovered; and in the other, after ligature of the vena portæ, blood

was found in the Receptaculum Chyli, and lower part of the thoracic duct.

It is at all events certain that, during digestion, there must be a great increase in the quantity of fluid passing from the mesenteric veins into the vena portæ and liver, for two reasons, 1. Because, in the distended and excited state of the stomach and intestines, the quantity of blood entering these veins from the arteries is much increased. 2. Because much, of the thinner fluids at least, received into the stomach, is absorbed by these veins.

But the branches of the vena portæ, within the substance of the liver, cannot be much distended; and therefore it is to be expected that, during digestion, either the contents of the gastric and mesenteric veins, leading to the liver, will stagnate and distend these veins, or else, if their blood makes its way readily through the vena portæ and liver, that other branches of the vena portæ must suffer distention in their stead.

Now, there is no evidence of any great distention of the gastric and mesenteric veins themselves during digestion; but it appears from the observations of BICHAT, Sir E. HOME, LEURET and LASSAIGNE, and others, that the *spleen* becomes obviously engorged with blood during that process, or even after copious draughts of liquids.

These considerations have induced LEURET and LASSAIGNE to think, that the chief use of the Spleen (which is known not to be of essential importance in the animal economy, as animals bear its extirpation

without much inconvenience, but which is obviously an appendage to the stomach, intestines, and liver), is to suffer venous congestion, instead of the bowels themselves, during digestion, and thereby to allow the venous circulation through the liver to be equable and uniform, although the source whence the venous blood comes is liable to so great variation. And the very vascular and distensible structure of the spleen, the great size of the vein leading from it to the liver, and the correspondence of its diseases to those of the liver, may be stated as farther evidence in favour of this hypothesis.

It is important to be aware, that the time in which the process of Digestion is completed, and probably the amount of nourishment procured by it from a given quantity of food, vary considerably in individuals in perfect health.

We must not suppose, that we understand the whole change which is wrought on the food taken into the stomach, when we have stated its chemical changes, and its course, up to the time when it is finally mixed with, and assimilated to, the blood. As we found that the blood possesses truly Vital properties, so we can have no doubt that, during the process of digestion, these properties are communicated to a part of the nourishment taken, probably to that part of it which takes the form of *globules*.

The process of Digestion is much influenced by mental Emotions and Sensations; but no part of it is influenced by any Voluntary efforts of mind, from the

time that the food enters the œsophagus, until its residue, unfit for assimilation, along with the biliary matter, and some part of the other secretions of the alimentary canal, arrives at the rectum.

The rectum is closed by the permanent tonic contraction of the sphincter ani, which is strictly a voluntary muscle, and the relaxation of the usual contracted state of which is within the power of the mind.

When the sphincter is voluntarily relaxed, the peristaltic movements of the rectum, excited by its distention, suffice, in general, for the expulsion of the fæces.

The sensations which the feculent matter here excite, are more distinct than those excited by it in the higher parts of the canal. When felt more distinctly than usual, they give occasion, in the first instance, to an effort which is truly instinctive, by which the sphincter ani is forcibly closed, and their escape prevented; but when these sensations become intense, they excite, more directly, a contraction which is quite involuntary, of different and distant voluntary muscles,—viz. of the diaphragm, which descends as in inspiration,—of the arytenoid muscles, which close the glottis and keep the chest distended,—and of the abdominal muscles, which, acting against the contracted diaphragm and distended chest, forcibly compress the viscera, and aid the peristaltic movements of the rectum in expelling the fæces.

The influence of the sensation of the rectum in producing this movement is well seen in the tenesmus,

which results from the increased sensibility of the mucous membrane of this part when inflamed, although little or nothing be passing along it.

The discharge of urine from the bladder is in like manner prevented, in general, by the tonic contraction of the levatores-ani muscles, and of those called acceleratores urinæ, and muscle of WILSON, (probably much more than of any of the fibres of its own muscular coat, which is strictly involuntary), and at times more forcibly restrained by voluntary contractions of these muscles, which compress the origin of the urethra. The bladder is emptied, in ordinary circumstances, simply by voluntary relaxation of these, giving effect to the contraction of the bladder, which is caused by the distention and irritation of its mucous membrane; but when the sensation resulting from distention of the bladder is intense, or when the sensibility of its mucous membrane is much increased, or the discharge of the urine difficult, the same simultaneous action of distant muscles is excited, as in the case of the rectum, to secure the forcible evacuation of the bladder.

When the function of Digestion, now described, is suspended by the denial of aliment, but thirst is allayed by drinking water, the consequences are, gradually increasing emaciation and debility; a sense of faintness takes the place of hunger; all the functions are performed slowly and imperfectly; the tunica conjunctiva of the eyes becomes inflamed (probably from the deficiency of secretion, and consequent action of

the air on the membrane), and death takes place very gradually, at very different times after the last food was taken ; but, in the human species, sometimes not until after forty days or more. Much longer fasting has no doubt been borne in some cases, chiefly by persons in whom the vital functions had been previously languid ; but the moral evidence of many reported cases of the kind is doubtful. After death, the most remarkable appearances, besides the mere wasting and deficiency of blood in the vessels, are, the distention of the gall-bladder by bile (the flow of which is neither solicited, as in the natural state, by irritation of the mouth of the ductus communis choledochus, nor promoted by the distention of the stomach) ; the contracted state of the stomach and bowels ; and frequently marks of inflammation in their mucous membrane ; probably likewise the effect of deficient secretion on that membrane, and consequent irritation by their contents.

The effect of total abstinence both from food and drink is to produce febrile excitement, perhaps a more active inflammation of mucous membranes, and subsequently a more rapid depression of strength, and death in less than half the time above stated.

SECTION XII.

OF THE EXTERNAL SENSES.

HAVING completed the view of those functions which are concerned in the preservation of the organized frame, we proceed to a more detailed account of the strictly Animal Functions, which are connected with the Nervous System in the living body, and are manifestly the object of Nature in the construction of the animal machine.

The general conditions requisite for all the Sensations, viz. the circulation of arterial blood in the parts concerned, the presence of certain nervous filaments, and integrity of these up to the base of the brain, have been already stated. Some farther condition in the state of the Nervous System is no doubt necessary, although it has not been detected ; for cases frequently occur where, notwithstanding the presence of all those mentioned, the nerves of sense are unfit for their office.

The word Sensation is properly restricted to that kind of change in the state of the mind which immediately follows, and informs us of, an impression on any of the senses. A little attention to what passes rapidly in the mind on these occasions, enables us to recognise the important distinction drawn by Dr REID and others, between this change, in which the mind is truly *passive*, and the judgment we are immediately led to form of the external existence, and

the notion we are often led to form of the nature, of the cause of the feeling which we experience; *i. e.* of the quality of some external object which it immediately suggests to us, and of which, through it, we have the *Perception*.

Various other mental acts, such as the Consciousness of our own existence, the recollection of past sensations, and belief in our own identity, the general notion of Time, connect themselves, even with some of the simplest acts of sensation. And as almost all sensations are either pleasant or painful, and many very fruitful sources of pleasure, they constitute a very important source of enjoyment, and motive to action. But at present we leave out of view all these ulterior consequences of sensations, and confine ourselves to the enumeration of the different sensations themselves;—to a statement of the particular conditions under which the Nervous System is impressed, in the case of each;—and to a short analysis of the inferences immediately drawn by the mind, touching the properties of external things, which are thus made known to it, or perceived by it. Some of these inferences are *natural* or intuitive, and others *acquired*; but the line of distinction between these classes of perceptions is not easily drawn.

In the lower animals, the mental acts excited by Sensation are much less numerous and diversified than in man; but the sensations themselves are often more acute; the pleasure immediately attending them probably equally intense; and certain immediate inferences from them, or Perceptions of the qualities of

objects, more rapidly formed, so that the exercise of their senses requires less *education*.

A distinction was drawn by Dr GORDON* between Simple Sensations and Sensations of Emotion; the latter term being applied to certain feelings, exactly resembling those which may be produced by external agents, distinctly referred to individual parts of the body, and often attended with obvious physical changes there; which cannot be traced to the influence of any external agents, but distinctly follow the excitation of certain mental emotions. This distinction is important, but the term Sensations of Emotion is not sufficiently comprehensive to include all those Mental Feelings, exactly similar to Sensations, which may proceed from internal causes only, independently of any impression from without on the organs of sense.

Simple Sensations are not so easily arranged into classes and genera as has been represented. Among the Higher or Special Sensations, felt only in consequence of impressions on individual organs, we should reckon not only those of Sight, Hearing, Taste and Smell, but also Hunger, Thirst, and the peculiar sensations of Anxiety at the lungs, already considered, and perhaps Nausea and Faintness; and the term Common Sensation should include not only what is commonly called Touch, but likewise the feelings of Heat and Cold, Pain, Itching; and another important class, which have been called Muscular Sensations, by which we are informed of the situation and extent of any muscular contractions which we voluntarily excite.

* Heads of Lectures on Physiology.

The individual sensations, referred to some of these genera, differ only in *degree*; but those referred to others have a manifest and original difference in *kind*—as Colours, Visible and Tangible Figures, Smells, &c. The individual sensations referred to the heads of Common Sensation, Sight, and Hearing, have differences according to the *position* of the objects causing them; those belonging to Taste and Smell hardly differ in that respect. Those only which belong to Common Sensation and to Sight differ according to the magnitude or *size* of the objects that excite them.

It is a general and important fact in regard to all sensations, that their intensity is very much influenced by Habit; they are felt strongly at first; and by continuance or repetition, at short intervals, the degree in which they are felt, and the portion of attention which they occupy, gradually diminish; and the emotions of pleasure or aversion which they occasion are not only blunted, but sometimes actually exchanged for one another. Impressions on the organs of Taste and Smell, which are at first unpleasant to most persons (such *e. g.* as those caused by tobacco or spirits), become gradually tolerable—then agreeable,—the want of them is felt as a painful privation,—and their cause must be applied in a gradually increasing degree, in order to produce the wanted effect. On the other hand, those causes which at first excite the most pleasing sensations, are successively followed by feelings of indifference, of satiety, and ultimately of disgust or aversion, if merely kept constantly before the organs

of sense. In this respect there is a striking analogy between sensations and muscular contractions. A similar law, as we shall afterwards find, applies to the action of poisonous or medicinal substances, which equally affect strongly the nervous system, but without distinctly exciting sensation.

In considering in detail the different sensations, and the information they communicate, we treat first,

OF COMMON SENSATION.

THE physical conditions requisite for the sensations of this class, are merely those general conditions relative to the nervous system, which have been already stated, and the healthy state of the organization of the textures in which it resides.

The simplest form of common sensation is that to which the name of Touch is commonly given, which results from the mere apposition of any external substance on most parts of the body. These parts, from their susceptibility of sensation from that cause, are said to be endowed with Common Sensibility; and, from mechanical irritation carried to a certain length, they are affected with Pain. It appears from the elaborate experimental inquiries of HALLER, that there are many textures in which this sensibility in the natural state is slight. Most of these are textures which have slight vascularity, particularly bones, cartilages, tendons, ligaments, fibrous membranes,

even cellular and serous membrane. All these textures are, however, the seat of acute sensation in certain circumstances, *e. g.* the tendons and ligaments, when forcibly stretched, and the fibrous and serous membranes, when their vascularity is increased, particularly by inflammation.

The internal parts of the solid viscera appear to have less sensibility than their membranous coverings; and the greater part of the brain, and the nerves of the special senses, seem nearly destitute of common sensation*.

The parts which are absolutely insensible (*i. e.* all sensations commonly referred to which are really seated in the adjoining textures), are those which are not vascular, the cuticle, nails, hairs, and bony substance of the teeth.

The parts in which common sensibility is the best marked, and employed for the most useful purposes, are the skin and the mucous membranes; and especially the very vascular and nervous papillæ on the fingers and on the tongue. The sensibility of the skin is blunted, as its other vital functions are restrained, by the intervention of the cuticle; that of all these membranes is manifestly increased by any increase in the flow of blood, and diminished by such causes as check the afflux of blood to them, *e. g.* by cold; that of the mucous membranes has the peculiarity of being apparently much less exalted by the state of inflammation than that of other membranes;

* HALLER, BICHAT, WILSON PHILIP, FLOURENS, MAGENDIE, &c.

perhaps because the capillary vessels of the mucous membranes, when distended by inflammation, are less compressed by adjoining firm textures than those of other membranes.

The sensation of Pain varies considerably, according to the different textures and parts of the body where it is excited. In many cases, its excitation may be referred, both in the healthy and diseased state, to the principle of mechanical pressure or irritation acting on sensitive nerves in one way or another: but there are other cases where the mode of its excitation is quite unknown. As residing in some parts, it is blended with the feelings of nausea and faintness, as from violent injury or disease of the abdominal viscera; and the effects which may be traced to this combination are of great importance in pathology.

The sensations of Heat and Cold are felt chiefly in the skin, distinctly in the mucous membrane of the alimentary canal, but hardly at all in that of the air passages, in the lungs, or other viscera. Whether they are dependent on peculiar nervous filaments is still doubtful. These sensations are remarkably dependent on the state of the capillary circulation on the surface, and more rapidly altered by changes in that respect than the actual temperature is. In consequence of the operation of causes which excite or strengthen the cutaneous circulation, cold is often little felt, when the temperature of the air in contact with the body is very low; and in consequence of the operation of causes weakening that circulation, it is

often much felt when the temperature is moderate. These sensations are likewise peculiarly influenced by habit, and therefore dependent on the state of the temperature applied previously to the change which excites them ; and farther, they are sometimes felt in consequence, not only of internal causes altering the state of the circulation on the surface, but of internal causes acting probably in the nervous system only, and unattended with any such perceptible effects. It is of great importance to keep in mind these different causes, independent of the actual state of the temperature, which influence the production of the sensations of heat and cold, when we speculate on the efficacy of these agents either in producing or counteracting disease.

The different sensations which we refer more strictly to the head of Touch, using that term as applied to feelings in which the mind is merely a passive recipient of impressions from without, belong only to two heads, Extension and Resistance ; and by these we are informed, in some degree, of the magnitude, and of the hardness or softness, roughness or smoothness, &c. of objects.

There are differences, also, in the sensations of Touch, corresponding to the figure, and more especially to the position, on the sensitive surface of the body, of the objects perceived by this sense ; but it seems to be only by experience that we learn to connect certain differences in our sensations, either with the particular figures of objects, or with the particular parts of our bodies on which impressions are made. These may be called, therefore, Acquired Per-

ceptions of Touch, although founded on original differences of Sensation.

The sense of Touch, without any active or voluntary effort, would probably suffice to convey to us the notions of extension or space, and of hardness or solidity, which are the essential elements in the idea we form of matter, and have therefore been called the *Primary Qualities of Matter*. But the information obtained in this way, particularly the knowledge thus acquired of Forms, would be very vague and imperfect. Our knowledge of these is acquired with much greater rapidity and precision, by the combination of the mere feelings of Touch, with the *muscular sensations*, already noticed, which inform us of the contractions of voluntary muscles, that are employed in moving the organs of Touch; and of the degree and extent of resistance, opposed to these movements of the organs of Touch, by the solidity, the figure, and the position, of tangible objects. It is by the number and variety of these muscular sensations which it can combine with distinct feelings of Touch, that the human hand is so admirably fitted for procuring information as to the size, form, weight, and character of the surface, of external objects.

These muscular sensations are likewise an important source of enjoyment, particularly in early life; their absence is a serious privation, and the effect of their excess is the uneasy sensation of Fatigue.

The distinction of the mere passive sense of Touch, from the combination of this with voluntary movements of the organs employed, made known by the

muscular sensations that accompany them, is well stated by MAGENDIE, in distinguishing the words Tact and Toucher; but the importance of the latter complex sensations to the acquisition of knowledge by the senses is more fully illustrated by Dr BROWN*, than by any other author.

It is by this process that we acquire precise and accurate knowledge of the figures and other primary qualities of external things, and the process is necessary to correct the more vague and fallacious notions of those matters which we derive from Sight; but the information acquired, whether by the active or passive exercise of the sense of Touch, is infinitely extended by means of Sight.

On comparing the feelings of Heat and Cold, with those sensations of Touch that communicate to us the notions of Extension and Resistance, and the mental processes consequent on these different sensations, we perceive the distinction between what are called the Secondary Qualities of matter, which are *known to us only as the causes of certain sensations* (and of other effects in the inanimate world); and what are called the Primary Qualities of matter, of which *our minds form clear and definite notions, perfectly distinct from the sensations by which they are suggested*; and which notions are the essential ingredients in the general idea that we have of the external world.

Both the primary and secondary qualities of objects are apprehended by us, in the adult state, and after

* Lectures on the Philos. of the Human Mind, Lect. 22-3-4.

long experience, as depending on causes external to ourselves (see p. 152). But it is more difficult to determine in what circumstances it is, that the notion of external and independent existence is first formed in the mind, or what conditions are essential to its formation. Perhaps the most reasonable supposition is, that the mere repetition of any sensation,—and the conviction of want of power on our part to cause, or prevent, or in any way affect, that repetition, as long as the circumstances in which it was felt continue unchanged,—are enough to suggest that notion to the mind. Some think that it is only on apprehending the existence of the primary qualities of matter, that we form that general notion; and Dr BROWN endeavoured to shew, that the notion could not be formed, but for the muscular sensations, which accompany the active exercise of the sense of touch, and the interruptions which these experience from the resistance of external things.

But these are in reality only questions of curiosity. The important fact is, that by the exercise of the senses, and especially of this sense of Touch, which informs us of what we call the primary qualities of matter, we are naturally led, not only to form that general notion of external and independent existence, but also to form more particular notions of Extension, Form, Hardness, Motion, &c., as qualities of external things, which *bear no resemblance whatever to the sensations*, through the medium of which we apprehend them. And one decisive proof of this being the true representation of this part of our mental constitution,

is obtained by attending to the idea of extension or Space ; which is undoubtedly formed during the exercise (whether active or passive, is immaterial at present) of the sense of touch ; and is no sooner formed than it “swells in the human mind to Infinity ;”—to which, certainly, no human sensation can bear any resemblance *.

OF SMELL AND TASTE.

THE Sensations of the Nose and Mouth may be considered together, on account of the intimate connexion which will appear to exist between them.

In order that the sensation of smell may be felt, the only special conditions necessary are, *first*, the passage along the internal nares, of air impregnated with certain effluvia which are believed to arise from many substances, but which manifest their existence in no other way than by the sensations they thus excite ; and, *secondly*, the healthy condition of the mucous membrane which lines the ossa spongiosa and other parts of the internal surface of the nostrils, especially, as it would appear, of the upper and middle meatus, where the 1st nerve is chiefly distributed. That some particular condition of the membrane is necessary to the sensation appears from the fact, that, unlike common sensation, it is diminished or lost in consequence

* See REID'S Inquiry into the Human Mind, chap. v., sect. 3-7. ; and STEWART'S Elements of the Philosophy of the Human Mind, Chap. i. Sect. 3. and 4.

of inflammation of the part ; but the nature of this particular condition is unknown.

It is necessary to distinguish between the special sensations, which odoriferous substances only can produce, and the sense of irritation in the nostrils, which any acrid or stimulating vapour or powder will occasion. The latter is the immediate cause of sneezing ; and it has been proved by the experiments of MAGENDIE *, confirmed by observations in some paralytic cases in the human body, that the sensibility to such irritation depends on the 5th nerve, and continues after the 1st nerve, usually called the Olfactory, is destroyed by injury or disease. It appears also, that by section of the 5th nerve, the sense of smell, as well as others of the special senses, is blunted or perverted ; but the distribution of the 1st nerve to the parts concerned in this sense, and to no other ;—its greater development in proportion to the size and complexity of the organ of smell, in animals in which this sense is more exquisite † ;—some cases on record, in which the sense of smell was lost in consequence of disease of the origin of the 1st nerve, while the 5th was healthy ‡ ;—and the appropriation of the 5th nerve to common sensation in other parts ;—seem sufficient to shew that the 1st nerve is that most essentially concerned in the sense of Smell, properly so called.

This sense informs us only of the different varieties of a single secondary quality of matter, to which the

* Journal de Physiologie, tom. iv.

† See SERRES, Anat. Comp. du Cerveau, pp. 281 & 286.

‡ SERRES, p. 294.

term *Odour* is properly applied, existing only in certain bodies, and which extends itself, by an unknown medium, to some distance from them.

The sensation of *Taste* is commonly described as that which results from the contact of certain bodies, called *Sapid*, with the upper surface and tip of the tongue, inside of the gums, and palate, especially when rubbed forcibly between these; and which is aided by the action of the fluids of the mouth.

In the case of this sense likewise, we should distinguish the component parts of the complex sensation felt on such occasions. The sensation which informs us of what is strictly called the *Flavour* of any substance, is at once distinguished as bearing a strong resemblance to smell; and the following facts seem sufficient to prove that it is in fact the sensation of smell, produced by effluvia from the substance held in the mouth passing through the nostrils during expiration.

1. When the mucous membrane of the nostrils is inflamed, the flavour even of sweet, bitter, or acid substances is not perceived, although there be no symptoms of disease in the mouth, and all the other sensations felt there are natural.

2. By carefully inspiring, during the whole time when a *sapid* substance is held in the mouth, or by carefully expiring through the mouth only, its flavour may be rendered imperceptible, even though it be rubbed repeatedly between the tongue and palate; a sense of what is usually called irritation or pungency, more or less acute, according to the nature of the sub-

stance in the mouth, only remaining; but, on the slightest expiration through the nostrils, the true flavour becomes immediately distinct.

When the various sensations which appear from these facts to belong strictly to the sense of smell, are carefully distinguished from the others, which are felt in the mouth, although these last may appear both acute and peculiar, it seems very doubtful whether they amount to more than very fine sensations of touch, produced chiefly by fluid substances penetrating the papillæ of the tongue. They hardly appear to merit the title of a special sense, any more than those feelings in the nostrils which prompt to sneezing, or those in the larynx which prompt to coughing. And accordingly, it will be observed, that there is no special nerve for the sensations in the mouth, the papillæ of the tongue having their nervous branches from the third part of the fifth.

The mixt sensations, probably referable to the heads of Smell and of very delicate Touch, which have their seat in the nostrils and mouth, are not only the occasion of much enjoyment, but have evidently two important uses, in reference to the function of digestion. 1. To excite the flow of the mucus and saliva, which are to aid in preparing the food for the action of the stomach. 2. To inform us of qualities in the objects that excite them, which bear a certain, though not a uniform, relation to their fitness for digestion.

OF SIGHT.

IT is here necessary to recal to recollection the structure of the principal parts constituting the organ of sight; first, the protection given to the eyeball by the eyebrows and eyelids, and the lubrication of its surface by the tears descending from the lachrymal gland, and no doubt also by the thin mucous fluid that exudes from the tunica conjunctiva: next, the different coats of the eyeball; the conjunctiva covering its fore part; the firm and strong sclerotic coat, which bounds and encloses the essential parts of the organ, and connects itself, in front, with the prominent and transparent cornea; the vascular and opaque choroid coat, terminating in front in the annulus albus at the root of the iris, and in the ciliary processes behind the iris; and within it, the nervous expansion called the Retina, the concave surface of which is spread over the thin membranous capsule that contains the Vitreous Humour; in front of which humour, the coats of the eyeball enclose the dense transparent Crystalline Lens, and the thin aqueous humour, divided into two compartments by the opaque and coloured iris: lastly, the entrance of the optic nerve, and its expansion to form the retina, on the inner side of the axis of the eye,—its passage through the sphenoid bone, and within the cranium, to the place of its union with its fellow on the opposite side,

—and its winding course across the *crus cerebri* and along the lower and outer edge of the *thalamus*, till it reaches the *corpus quadrigeminum*.

The aqueous and vitreous humours of the eye contain about 2 per cent. of animal and saline matter, and the crystalline lens, which is solid, and denser towards its centre than on its exterior, contains 42 per cent. of animal matter and salts.

In order that the Sensations enabling us to perceive light and colour should be felt, the only special condition probably is, that light, by which we mean the external cause of these sensations (generally believed to be an imponderable substance), should impinge on the retina. But in order that this light should give any distinct information as to the form or other qualities of the objects whence it comes, it is necessary that it should be so affected by the coats and humours of the eye, as to form a distinct image of these objects on the retina at the bottom of the eye.

That such images of external things are really formed on the *Retina*, has been shown, by fixing the eye of an animal just killed in a small aperture of a darkened room, stripping off carefully the opaque sclerotic and choroid coats at its back part, (or, in the case of albino animals, without that preparation), and inspecting the posterior surface of the retina. *MAGENDIE* was even able to show, in such experiments, by drawing off successively the different humours, the importance of each of these in the formation of the images.

In order to understand how this is effected by the

eye, it is necessary to attend to the following optical propositions, the truth of which is known, partly by experiments, and partly by mathematical deduction from principles which these experiments had established.

1. When light passes through any single transparent medium, it moves always in straight lines.

2. When it passes from one transparent medium to another, unless it falls perpendicularly on the surface where they join, it undergoes a change of direction, or is *refracted*; and we judge of the mode and degree of its refraction by supposing a perpendicular drawn to the surface of junction of the two media, at the point where the ray quits the one and enters the other, and observing whether, in its course through the second medium, its change of direction is towards, or from, that perpendicular. If it be refracted towards the perpendicular, the medium which it enters has the *greater refractive power* of the two; but if from the perpendicular, it has the *less refractive power*. The angle which the incident ray makes with the perpendicular is called the Angle of Incidence, and that which the refracted ray makes with it the Angle of Refraction; and the greater the difference between these two, the greater the difference of refractive power of the media.

3. On comparing the course of rays which fall with *different degrees of obliquity* on the surface of junction of the *same media*, it is found that the refractions they respectively suffer bear a certain propor-

tion to the degree of their obliquity; the sine of the angle of incidence having to the sine of the angle of refraction always the same ratio.

4. Denser bodies have, in general, a greater refractive power than rarer; and accordingly, water, glass, and the transparent parts of the eye, have a greater refractive power than air.

5. When a ray of light passing through air falls obliquely on a convex lens of glass (*i. e.* a piece of glass bounded on each side by a segment of a sphere), or of any other transparent matter of greater refractive power than air, it necessarily undergoes one refraction where it enters, and another where it leaves the lens, and each of these brings it nearer to the axis of the lens;—*i. e.* to the straight line which joins the centres of the two spheres, segments of which bound the lens.

6. When different rays, coming from the same point, and traversing air, fall on such a lens, and each, after the two refractions it undergoes, is brought towards the axis of the lens, the point of that axis towards which they tend is determined, almost exactly, by three conditions,—by the distance of the point from which they come,—by the degree of convexity of the surface of the lens,—and by the degree of its refractive power, that is, by the proportion of the sine of the angle of incidence, to the sine of the angle of refraction, of all rays that enter it from air. Now, these three conditions are the same in regard to all the rays that issue from any one point; and therefore, if the refractive power be such as to bring any one ray from that point

to intersect the axis of the lens, it will bring all the rays from that point to intersect the axis at the same place; *i. e.* it will concentrate all the rays from that point into a *focus* beyond the lens.

7. Every double convex lens in this manner draws together into a focus all parallel rays, *i. e.* rays coming from a point at an infinite distance; and the fixed point to which these tend is called the principal focus of the lens: And farther, every such lens draws together into a focus all the rays coming from any point more distant from itself than its own principal focus; but the rays from a point at the distance of that focus become parallel after passing through the lens; and those from a point nearer than that, diverge after passing through the lens, although in a less degree than before entering it.

8. As a convex lens concentrates all the rays from a distant *point* into a *focus*, so it concentrates all the rays from a distant *object* into an *image*, which will be nearer the lens, and smaller, as the object is the more distant, and the refractive power greater; and which will be *inverted*, because the rays from any point of a luminous object, which lies on either side of the line that is a production of the axis of the lens, must necessarily cross that line, after the two refractions they suffer, before they can be concentrated.

Now, in the eye, although the apparatus is more complex, yet the effect on light from a point, or from an object placed before the eye, is necessarily the same as would be produced by a double convex lens.

The ray which falls from any luminous point perpendicularly on the centre of the cornea, and passes through the axis of the eye, undergoes no refraction. All other rays coming from the same point, and forming a long narrow cone of light between it and the pupil, are refracted, first where they enter the cornea and aqueous humour,—then where they enter the crystalline lens, which has the greatest density and refractive power,—and lastly, where they pass from the crystalline into the vitreous humour. All these refractions are towards the axis of the eye, and these rays meet the one that passes along the axis in a focus. And as the humours of the eye draw together all the rays entering the pupil, from a luminous point placed before it, into a focus, so they draw together the rays from an object, or set of objects, into an image, which is necessarily placed *somewhere behind the crystalline lens*, and is *inverted*.

In the usual and natural state of the eye, its transparent parts are fitted, by their refractive power, for concentrating parallel rays (or rays from a point at an infinite distance), just at the Retina, *i. e.* the *principal Focus of the eye lies at the Retina*, and therefore clear and definite images of very distant objects, the rays from any single point of which are almost exactly parallel, are formed on the retina, and the eye is fitted for the vision of these distant objects. And as the divergence of the rays which come from a single point, even a few feet distant from the eye, and fall on so small an area as the pupil of the eye, is very trifling, the eye is equally fitted, in its natural state,

for all practical purposes, for the distinct vision of all objects situated more than a few feet from it.

But in the natural state of the eye, after it has been employed in distant vision, when an object is brought within two or three feet of it, the rays from that object converging to form an image beyond the retina, it is at first seen indistinctly, and an effort is voluntarily or instinctively made, by which the eye adjusts itself to the distinct vision of this object; and if it be brought still nearer, the eye may be made to continue this effort of adjustment, till it come within about five inches of the eye; after which, the refractive power of most eyes is insufficient for bringing together the rays on the retina, and the object is seen indistinctly.

The effort by which the eye increases its refracting power, and adjusts itself to the distinct vision of an object thus approaching it, may be observed to be attended with a contraction of the pupil; and Dr BREWSTER found, that the application of bright light to the eye, whereby a sudden contraction of the pupil is effected, causes the eye to adjust itself to vision at a shorter distance than previously*; and Dr WELLS shewed, that when the iris is palsied, as by belladonna applied to the eye, the power of adjustment to distances is lost †. But the mere elongation or shortening of the iris, although it alters the size of the cone of light passing from any luminous point to the pupil, and therefore alters the illumination of the

* Edinburgh Journal of Science, vol. i. p. 77. 1824.

† Philosophical Transactions, 1811.

image formed at the back part of the eye, does not alter the refractive power of the eye. The adjustment of the eye must therefore be produced by some other change, contemporaneous with the contraction of the pupil.

The manner in which this is done is still uncertain ; but the most probable supposition is, that it is by a vital contraction of the annulus albus, or ciliary ligament at the root of the iris, simultaneous with the contraction of the sphincter iridis, and which will have the effect, either of increasing somewhat the convexity of the cornea, or of bringing the crystalline lens somewhat forwards, and of course bringing forwards also the image, previously formed behind the retina *.

The usual movements of the iris (probably of its sphincter muscle, though that is not easily demonstrated), are caused by the impression of light on the retina, and no doubt, in the natural state, by the sensation of light felt in consequence of that impression. When the light is diminished the pupil expands, the cone of light coming from any one point to it is augmented, and the focus of that point (or the image of an object of which it makes a part) is rendered more luminous than previously ; and the reverse change happens when the light becomes more intense ; so that this is a moveable curtain, placed before the eye to regulate the quantity of light admitted into it, and which is moved by the very sensations which call for its intervention †.

* See KNOX, in Trans. of Edinburgh Royal Society, vol. x, and BREWSTER, in Edinburgh Journal of Science, vol. i. 1824.

† See WHYTT on the Vital and Involuntary Motions, § vii.

Accordingly, Mr MAYO found that the iris could be made to contract, either by irritation of the optic nerve, within the cranium of a bird, or by irritation of the third nerve, which is perhaps the only motor nerve that sends filaments to the ophthalmic ganglion, whence the ciliary nerves, passing to the iris, are derived*.

The orbicularis oculi muscle, which closes the eyelids, and has been shewn by Mr BELL to be moved by filaments of the portio dura, is also obedient to the sensation of light, when that sensation is so intense as to require the complete removal of its cause to prevent acute suffering, and subsequent loss of the powers of the retina and optic nerve.

The aperture of the pupil obviously admits rays of light only to a part of the concave expanded surface of the retina, and this illuminated part is farther diminished when the pupil is contracted. Accordingly, the *field of vision*, when the eye is kept at rest, is very limited. According to the observations of Dr YOUNG, it extends upwards to objects situated in a line forming an angle about 50° with the optic axis, downwards to 70° , inwards to 60° , and outwards to 90° .

But it is farther obvious, on attending to what is seen when the eye is fixed on a single object, that the field of *distinct* vision is much more limited than this; any object situated in a line which makes an angle of 5° with the optic axis, is seen very indistinctly.

From this we learn, *first*, the importance of the muscles of the Eyeball, by which the eye is easily

* Anatomical and Physiological Commentaries, No. II.

moved, voluntarily or instinctively, so as to bring its axis to bear on any object that is to be examined, and secure distinct vision of it; *secondly*, the peculiar sensibility of that portion of the organ which lies in the axis of the eye, exactly opposite to the pupil.

Just at this point there is found, in the human eye, and in certain animals, whose vision is very acute*, the central foramen, or opening in the retina; the dimensions of which, after death, are such, that it would seem that the images which give the most distinct vision must be formed within it.

How the change in the optic nerve, necessary to the sensation of sight, should be produced by an impression, thus apparently made on a point, which the nervous filaments do not themselves reach, it is at present impossible to explain; but the observation should perhaps be connected with another, viz. that in birds, reptiles, and fishes, many of which are endowed with a more penetrating sense of sight than ours, an empty space is in like manner found at the other extremity of the filaments composing the optic nerve, viz. in the Corpora Quadrigemina†.

Another peculiarity in regard to the sensibility of the retina is, that those rays of light which are concentrated on the part, on the inner side of the optic axis, where the optic nerve enters, are found to cause no sensation; as is easily proved by fixing the right eye on two small objects placed together on a plain surface, then moving the one of these objects gra-

* See KNOX, in Edinburgh Phil. Trans. vol. x.

† SERRES, Anat. Comp. du Cerveau, pp. 197 & 304.

dually to the left, and keeping the axis of the eye directed towards it, while the attention is fixed on the sensation communicated by the other object; the existence of the insensible spot on the retina is then quickly discovered. It has been conjectured that this depends on the entrance, not of the optic nerve, but of the central artery of the retina which it encloses.

The experiments of FLOURENS have unequivocally shown that, in many of the lower animals, the Corpora Quadrigemina, where the optic nerves originate, are the only parts of the larger masses of the Nervous System concerned in the mere sensations of the eye*.

What has been said of the conditions in the eye, necessary to vision, sufficiently explains most cases of blindness; and likewise enables us to understand the nature of the imperfections of this sense called Presbyopia and Myopia. In the former, the eye has generally become somewhat flattened, and has lost somewhat of its refractive power, so that the images of near objects, seen by diverging rays, are formed a little beyond the retina; and a convex lens is useful, to diminish the divergence of such rays before they enter the eye,—cause them to converge sooner in passing through it,—and thereby render the images they form on the retina definite and distinct. In the latter, the eye has generally a more convex form,—has an excessive refracting power, so that it is naturally adjusted to the distinct vision of near objects;—and its focus of parallel rays, by which distant objects are

* Recherches Experimentales, &c. p. 150.

seen, being a little in front of the retina, these are seen indistinctly ; unless a concave lens is employed, to give a little divergence to the rays coming from them.

These are the most important principles that have been ascertained relative to the conditions, in each eye, necessary to distinct vision. But in general, both eyes are employed ; and the condition which is necessary, in order that an object, at any distance, may appear single, although an image of it is formed in each eye, appears to be merely this, that the axes of the two eyes shall be fixed on the same point of the object ; for which purpose, the motor nerves and muscles of the eyeball, instinctively act together, even from the time of birth. The necessary effect of this is, that the rays coming from all the points of the object in question, are concentrated upon *corresponding points* of the retina of the two eyes ; that is, upon points similarly situated in regard to the centres of the retina of the two eyes ; and experience shows that, in these circumstances, objects are seen single, but that, when their images are not formed on corresponding points of the retinae, they are seen double. Of this there are several simple proofs. 1. When the axes of the eyes are fixed on a near object, and the attention at the same time directed to a distant one ; this last, the image of which cannot be formed on corresponding parts in the two eyes, is seen double, and *vice versa*. 2. When pressure is made on the ball of one eye, so as to prevent its axis from being directed to the same point as the axis of the

other, any object that may be looked at is seen double ; and the same occurs in Squinting, or distortion of the eyes, although as, in most of these cases, the sensibility of one eye is much feebler than that of the other, the one image only is usually made an object of attention. 3. When two distinct objects are placed carefully in the lines of the axes of the two eyes of a person who squints, or whose eyes are distorted, as their images are necessarily formed on corresponding points of the retinae, they are seen to coincide. 4. When two objects are held close to the two eyes, and exactly in their axes, as the optic axes cannot be directed to the same point in either of them, and as their images, although necessarily very faint from their proximity to the eye, must fall on corresponding points of the retinae, so they are seen, although indistinctly, yet evidently as coinciding*.

We can go no farther, with confidence, in determining the conditions requisite for single vision, than to illustrate the general proposition above stated. It was conjectured by NEWTON, that single vision may depend on a semi-decussation of the optic nerves at their commissure, whereby the right half of each retina might be in communication with the right hemisphere of the brain, and the left half of each with the left hemisphere ; the consequence of which may be easily conceived to be, that the *corresponding*

* See REID's Inquiry into the Human Mind, Ch. vi. sect. 13. The objections stated to REID's principles on this subject by Dr WELLS (Essay on Single Vision), seem to be founded on misconception.

points in the retinae of the two eyes may be connected with, and their sensibility depend upon, *the same points* in the brain. Different anatomists have agreed as to the semi-decussation of the human optic nerves; and Dr WOLLASTON has supported the theory, by reference to the known fact, that, in a transient diseased state of vision (the *suffusio dimidians*), one half of each retina is occasionally insensible to the light at the same time*. But the anatomical evidence of this theory, as applied to the human species, is defective. In many other animals, it appears certain that the decussation of the optic nerves is complete; but, as most quadrupeds and birds have their eyes placed more laterally than the human eyes, and are accustomed often to regard objects with one eye only, the analogy of their structure is perhaps not to be trusted.

In order that any object of sight may appear *above* the optic axis, it is necessary that the image formed by it on the retina be *below* that axis, or, more generally, the object always appears to be in the direction of a line, drawn from its image on the retina, through the centre of the refracting parts of the eye. This appears from our seeing objects erect, although the images they form are inverted; and is farther illustrated by the following fact. If a small object, brightly illuminated, be held within an inch of the eye, and inspected through two very minute holes, set close to one another in a card, two faint images are formed of

* Phil. Trans. 1824.

it (by rays already converging before they reach the eye, and which do not cross the axis before reaching the retina), on different points of the retina; and it is seen double, although by a single eye; and, by closing one or other of the holes in the card, it is found that the image which appears uppermost is formed by rays which pass through the lower hole, and therefore is formed on the lower part of the retina, and *vice versa* *. But this principle must likewise, at present, be held to be an ultimate fact on this subject.

The images formed on the retina certainly differ as to colour, as to illumination, as to size, form, and position; and it is obvious that, in the adult state, the different sensations they excite not only inform us as to light and colours, but also as to the size, forms, position, and distance of objects. But it is difficult to judge how far the notions on these last points, which we connect with them, in the adult state, are simply dependent on them, or how far they are acquired by the sense of touch, and only suggested by the sensations of the eye, in consequence of experience, and association with those of touch.

The notions we have of the brightness, and of the colours of objects, are necessarily and entirely dependent on the sensations of sight. The colour depends on the part of the compound ray of light which each object reflects or transmits; and the perception of it

* See REID's Inquiry, &c. Chap. vi. sect. 12.

depends on a peculiar sensibility of the optic nerve, which is not enjoyed, in an equal degree, by all men, of perfectly distinct vision in other respects.

The forms of the images of external things, which are formed in the eye, differ so widely from their real forms, that we should probably not be able to form the notion of any complex form by this sense, unassisted by the sense of touch. Neither is it possible that the differences of sensation that correspond to the differences of the magnitude and position of objects, can suffice to inform us of their real size or real position. And the distance of any object from the eye, being measured by a straight line drawn from it, which, to the eye, must appear as a point, cannot of course be a direct object of sense. Nor can any reasoning, on the mere sensations of sight, furnish just conclusions as to these points. All these are, therefore, usually considered as *Acquired Perceptions of Sight*; *i. e.* it is supposed to be by experience, and by comparison with the information acquired by the sense of touch, that we learn to associate the differences, in these respects, of the sensations we feel, with the actual circumstances of the external objects from which they proceed; and some have supposed that it is only in the same way that we learn that objects, seen by inverted images, are really erect, and even that we learn to distinguish the numbers of visible objects.

The instances of persons blind from infancy, who were restored to sight by Mr CHESELDEN*, Sir E.

* Philosophical Transactions, vol. xxxv.

HOME*, and Mr WARDROP†, are sufficient to shew that the notions of position, form, distance, and size of objects, suggested by the newly acquired sense of sight, were very imperfect and erroneous. We can observe, even in the adult state, that our ideas of form and position are much aided and corrected, if not acquired, by touch; and our ideas of the latter by the muscular sensations which accompany the actions necessary to fix the optic axes on any object of sight; that the judgment, as to size, from sight, is dependent on a previous judgment of distance; and that our estimates of distance are very liable to error, and are assisted, if not acquired, by help of different kinds of experience,—by the effort made to adjust the eye to distinct vision, when the object is very near,—by the degree of inclination of the optic axes requisite to fix both eyes on it, when it is rather more remote,—by the degree of vivacity of its colours,—by the distinctness of its minute parts,—and more especially by the number, and the known size, of intervening objects.

But although it is certain that a *great part* of our judgments on these points, connected with the sensations of sight, is really acquired by experience and education, we should not hastily conclude, that the differences in our sensations, corresponding to these circumstances of external objects, may not suggest to us, even prior to experience, *some part* of the conclusions which we habitually draw from them. For we

* Philosophical Transactions, 1807.

† Ibid 1826.

know that many of the lower animals form, and act on, correct judgments of the position, size, and distance of objects, immediately on coming into the world ; and that we ourselves, in various other instances, both act instinctively, we know not why ; and acquire knowledge intuitively, we know not how *.

OF HEARING.

IN examining the organ of this sense, we see indications of much contrivance, the uses of which are not understood, because the laws of the transmission of sound are not so well known as those of the transmission of light ; and therefore it is to no purpose to enlarge on them.

The condition necessary to the sensation appears

* Dr BROWN makes the following observation on objects being seen single and erect, by means of two inverted images on the retina. " If the light, reflected by a single object, touched by us, had produced not two only, but two thousand separate images, erect or inverted, the visual feeling thus excited, however complex, would still have *accompanied the touch of a single object* ; and if only it had accompanied it *uniformly*, the single object would have been suggested by it, precisely in the same manner as it is now suggested." But is it not a sufficient answer to this doctrine, at least as far as regards single vision, to observe, that to a man who has a permanent squint, or distortion of the optic axes, the visual feeling always suggests double objects, although he knows, by touch, that they are single ? This fact proves, that there are conditions in the eyes themselves, as stated above, essential to single vision ; and consequently, that it is *not merely* by means of the *sense of touch* that we are led to a correct judgment on that point.

to be the communication of certain vibrations, of which many substances, in different degrees, are susceptible, to the branches of the auditory nerve which are spread over the different parts of the labyrinth; these vibrations may be transmitted by the bones of the head, as when a sounding body is placed between the teeth; but in order that impressions may be received by this sense from a distance, through the medium of air, the contrivance employed is complex; the vibrations of the air, derived from the sounding body, are first communicated through the meatus externus, which is lubricated by its oily secretion, the cerumen, to the outer chamber, or tympanum,—which is closed by a membrane where the impression is made on it, but filled with air from the posterior nares,—which is extended, in a very irregular form, into the mastoid process, and traversed by a chain of minute bones (furnished with muscles whereby they are, to a limited extent, moveable), one of which is fitted to the aperture that leads to the inner chamber or vestibule. This cavity is filled with a liquid like the aqueous humour of the eye, and communicates with different small winding canals, situated in the interior of the hardest bone in the body, and the membrane lining which is supplied, by many minute holes in the bone, with very numerous small branches of the portio mollis of the 7th pair of nerves. The whole of these cavities and canals, containing the fluid, have been generally thought to be the seat of this sense; but the experiments of FLOURENS, shewing that injury

or destruction of the semi-circular canals injures other functions indeed, but apparently not the sense of hearing*, render it probable that those parts of the 7th nerve only which supply the cochlea and vestibule, are essentially concerned in this sense.

Comparative Anatomy shews, that a shut sac, containing a fluid, and lodging the extremities of the 7th pair of nerves, is all that is essential to constitute an organ of hearing throughout the animal creation†.

The importance, in our species, of the different parts of the organ of hearing is shewn by deafness resulting,—1. From hardened wax in the air-passages. 2. From closing of the eustachian tube, which conveys air to the tympanum. 3. From separation and discharge of the small bones, and consequent discharge of the liquor from the labyrinth. 4. From disease of the 7th nerve, or of the adjoining parts injuring that nerve. And in the case of this sense, as well as of sight, there are also examples of its total deficiency even when all parts of the organ appear naturally formed, believed to be owing to some imperceptible defect in the 7th nerve, or its origin in the floor of the 4th ventricle.

The individual sensations of sound differ from one another, not only in intensity or loudness, which depends on the length of the vibrations of the body whence the sound proceeds, but also in two other

* Ann. des Sciences Naturelles, tom. xv.

† CUVIER, Leçon 13.

particulars, which are peculiar to them, viz. Tone and Timbre.

The tone, or pitch, of a sound, depends on the number of vibrations performed by the sounding body in a given time, being lower as these are less numerous, and higher as they are more. According to the observations of Dr WOLLASTON*, there are some persons who are totally insensible to certain very acute sounds, although they have the usual sensibility as to lower sounds.

The timbre of sound depends on the nature of the sounding body, and varies in every different musical instrument, although the note struck is the same. There are other differences in sounds, which cannot be so easily reduced to classes or genera.

Sensations of sound differ according to the direction of the sounding body, although it is difficult to understand how differences in this respect should reach the auditory nerves so as to affect them. The same sound coming from points, the directions of which from the ear make an angle of 10° or 12° , is felt to differ; but it is probably from experience only that we learn to connect these differences with the true directions of objects.

Our judgment of the distance of objects by means of this sense, is founded only on the intensity of the sound; and the intensity that corresponds to each distance is known by experience only, which renders the judgment liable to error. We know, for example,

* Philosophical Transactions, 1820.

by experience, the ordinary tone and loudness of conversation at ordinary distances. When, by reflection of sounds from concave surfaces, the same tones are heard louder than usual, we judge the distance of the speaker to be less than the reality; and in the state of syncope, when the same tones are heard fainter than usual, we judge the distance to be greater than the reality.

Those persons who can articulate distinctly during inspiration, produce sounds which have nearly the same tones as are heard in ordinary conversation, but are much more faint, and therefore deceive us as to distance; and this is an essential part of the art of the ventriloquist. But he has no such means of imitating those differences of sensation by which we judge of the direction of sounds; and can only attempt that by misleading the imagination.

What is properly called a Musical Ear differs, from the mere perception of minute differences of sounds, and recollection of their successions; and is characterized by the pleasure those possessing it derive from certain successions of sounds only; and by immediate observation of any deviation from the successions fitted to give this pleasure. The circumstances of organization on which it depends are quite unknown. By the habit of minute attention to the differences of sounds, it is susceptible of much improvement; but the pleasure derived from it being complex and much connected with associations, is probably by no means strictly proportioned to the degree of accuracy in which it is possessed.

Before leaving the subject of the external senses, it is right to mention the cases, in which causes internal to the body produce sensations, exactly similar to those generally produced by impressions from without.

Hunger, Thirst, Anxiety from the want of air in the chest, most cases of Pain, and other internal sensations, depend on causes internal to the body, but external to the nervous system; but there are some cases of pain in which there is no evidence of any cause, external to the nervous system itself. And there are two sets of well-known phenomena, important in pathology and practice, which must be regarded as affections of sentient nerves, from causes acting in other parts of the Nervous System. These are independent of the feelings which are strictly called Sensations of Emotion, which will be mentioned along with the other effects of emotions on the body.

I. The phenomena which are strictly called Sympathetic Sensations, are of this kind. These are cases where a sensation, distinctly referred to one part of the body, is known to be produced by an impression made on another part. Of these we may make two divisions.

1. The first is where a cause acts somewhere in the course of sentient nerves, or at their origin at the base of the brain or in the spinal cord, and the sensation produced by it is referred to the extremities of a nerve; because the part where it is excited is the same, where the nervous action, necessary to sensation, had formerly been produced by impressions made on those ex-

tremities. Such sympathetic sensations are illustrated by the sensations felt in the stump of an amputated limb, and referred to individual parts of the limb that has been removed. Of this kind, are the sensation of a flash of light from an injury of the eyeball or brain; the sensations of suffusions, of tinnitus aurium, of nausea, of aura epileptica, referred to the eyes, ears, stomach, or limbs, in consequence of peculiar diseases of the brain, no doubt affecting the origins of the nerves; the sensation of pain often referred to a paralytic limb, after an attack of palsy from diseased brain; the sensation of pain or tightness stretching round the chest or abdomen, from disease or irritation of the spinal cord, as in paraplegia; pains of various parts of the lower limbs from the pressure of aneurisms of the aorta on the spinal cord or lumbar nerves; and the slighter sensations of the same kind seen in hysterical cases, and stated to have been best relieved by remedies applied over the origin of the intercostal or lumbar nerves; the sensation of pain, often referred distinctly to the neck, back, or different limbs, in the course of hydrocephalus.

2. There are many instances of pains distinctly referred to one part of the body, but which are known, from experience, to proceed from irritation or disease of another part. These sympathetic sensations may, in several cases, be ascribed to connexions of the sentient nerves of the parts (especially when the part really injured is internal, and that to which the feeling is referred is external, and both have their sentient nerves from the same larger branches), and may so be

brought under the same head as the last ; but we cannot, as yet, refer all such cases to this principle.

Of this kind are, the pain of the shoulder from disease of the liver or diaphragm ; pain of the urethra and glans from disease or irritation of the bladder ; pain of the testis and thigh from irritation of the kidney ; pain of the side of the neck and head, and of the left arm, from disease of the heart ; pain of the back from disease or irritation of the uterus ; pain (and spasms) of the legs from irritation of the intestines in cholera ; pain of the knee from disease of the hip-joint in the morbus coxarius ; pain of the forehead from irritation at the stomach ; pain of the cheek or temple from irritation of a tooth ; itching of the nostrils from irritations in the bowels ; the uneasy feeling referred to the teeth from harsh grating sounds ; and various other less frequent sensations, in constitutions of unusual delicacy as to sensibility, which are distinctly referred to one part of the body, but traced to irritation of other parts.

In both these cases it is often observed, that there is not only the mistaken judgment, as to the seat of the cause exciting the sensation, but some physical effect (*e. g.* inflammation in a greater or less degree), follows in the part to which the sensation is referred, which implies that some change is really propagated downwards, along the sentient nerves of these parts to their extremities, which probably both excites their sensations, and may also influence the capillary circulation in their neighbourhood.

II. Another set of facts which must be referred to the head of sensations proceeding from internal causes, but exactly resembling those excited by impressions from without, consists of cases of Spectral appearances, or sounds, differing from the sympathetic sensations now considered, in being exact representations of certain definite impressions on the higher senses; and differing from mere recollections, or fancied scenes, in being equally vivid and distinct, and equally beyond the control of any voluntary mental effort, as the sensations excited by real impressions from without.

The most common case of such spectral appearances, is in persons under the influence, or recently recovered from the influence, of opium or of strong liquors; but they occur occasionally in persons of what is usually called nervous temperament, independently of any such cause*.

Cases recorded by Dr BOSTOCK, (*System of Physiology*, vol. iii. p. 204), and others prove, that these spectral appearances are not merely the repetition of past sensations, but, in some instances, differ from any thing that has ever been presented to the senses; in which case, their excitation implies the exercise of that mental power which is strictly called Imagination.

It was formerly stated, that the sensations, and other mental feelings, so easily reproduced during darkness and silence, after unusual muscular exertions, or unusually strong impressions on the senses,

* See the works of ALDERSON, FERRIAR, and HIBBERT, on Apparitions.

as well as other facts, pretty clearly indicate, that the nervous system is not passive during the performance of its different functions, but undergoes various, although imperceptible, changes corresponding to them all. It is probable that a slight degree of the same changes, which accompanied the original excitation of all sensations, may accompany every act of recollection of these; and that similar changes may attend acts of imagination, by which imitations of objects of sense are created in the mind (in which operations we shall find that the mind acts for the most part involuntarily); and if, on particular occasions, these physical changes are in any way rendered stronger and more enduring than usual, it is only in conformity with principles already stated, and to be afterwards more fully explained, that they should impress the mind, for the time, with the idea of the external and independent existence of the causes exciting them.

Various cases have been recorded, at different times, in which it was thought that, during a singular excited state of the nervous system (called Somnambulism or Reverie), slight impressions, on the sense of touch only, were followed by sensations in the organs of the special senses, which gave correct information of kinds coming within the province of these special senses. We cannot conceive that the conditions which appear to be essential to the exercise of these senses, can be imitated in this way; and the moral evidence, attending such alleged cases of transference of the sensual powers from one part to another, is very liable to suspicion; yet there is a strik-

ing similarity in the different cases of this kind, recorded by different observers, unknown to each other, which demands farther inquiries, before we can think ourselves entitled finally to reject such observations as mere fallacies*.

* See ROSTAN, Art. *Magnetisme Animal*, in the *Dictionnaire de Medecine*, and especially BERTRAND “*Du Magnetisme Animal en France.*”

SECT. XIII.

OF THE MENTAL FACULTIES.

THE sensations which we feel in consequence of external impressions, are manifestly instrumental in exciting, and are continually mingled with, certain other internal changes, of which we are conscious, and to which we give the general names of Trains or Successions of Thoughts.

The method of inquiry which it is necessary to pursue, in order to acquire satisfactory information as to these operations of our minds, is just the same as that which is followed in the physical sciences; consisting first in the careful observation, and then in the comparison and classification, of individual facts, whereby we acquire the knowledge of general principles, or laws of this department of nature; by reference to which other individual facts may be explained, when they have taken place, and be anticipated when they are about to take place. But as attention to the changes which take place in our own minds requires a peculiar and often painful effort, to which few men have carefully accustomed themselves, and as the words employed to denote the transitory thoughts or states of mind of which we are conscious, are necessarily analogical, and are very easily misapprehended, there has been a want of precision in the conduct of most inquiries on this subject, as compared with those

made into the laws of the material world ; and the results have been less satisfactory.

In particular, two important errors may be pointed out in the conduct of different inquiries on this subject. Some have assimilated them too much to physical researches ; have refused to acknowledge, or not appreciated the importance of, those distinctions among mental phenomena, which do not correspond to physical changes, either immediately preceding or immediately following them ; and have erred chiefly by excessive generalization. This is the most common error of physiologists, who speculate on these subjects.

Others again, estranging themselves too much from the simple observation of facts, have engaged in much visionary speculation, and in many verbal controversies regarding the mental phenomena, which not only lead to no practical result, but often appear to be directed to no definite object.

In order to avoid both those kinds of error, all that seems necessary is, *first*, To recognize the necessity of patient attention to, and *reflection* upon, the different thoughts that pass through our own minds, as the only foundation of accurate knowledge in this department of science ; *secondly*, To define strictly, and observe carefully, the meaning of all the words employed to denote the changes of which we are conscious ; *thirdly*, To understand distinctly the objects of inquiry into the operations of the mind, and the limits which nature has imposed on the gratification of curiosity on this subject, and which are just similar

to those, which circumscribe our researches in all other departments of science.

The first observation that may be made on the thoughts of which we are conscious, is that they are all *transient*, or in a continual state of change, one act or state of mind passing away, and another succeeding. Hence two inquiries naturally present themselves, which have not perhaps been so carefully distinguished as they might have been ; 1. Into the nature or characteristics of the different acts or affections of mind that succeed one another ; and 2. Into the laws which regulate their succession.

I. The exercise of our senses naturally and immediately leads us to form certain general ideas or notions, the tendency to the formation of which has been called by some metaphysicians, the Power or Faculty of Simple Apprehension ; and, in connexion with these, we have a natural disposition to put faith in certain propositions or principles, which have been called by Dr REID, Principles of Common Sense, and by Mr STEWART, perhaps more correctly, Fundamental Laws of Human Belief ; of which no proof can be given ; which we know not from Reasoning, nor from Experience, but by Intuition ; and our confidence in which must be stated as an *ultimate fact* in the constitution of our minds. A little attention to the existence, and to the authority, of these laws of belief, will enable us to set aside a great deal of useless controversy, and simplify our account of the mental part of our constitution.

Acquiescence in these principles is, in fact, equally necessary in the prosecution of physical, or even of mathematical science, as of metaphysics; but in the former sciences, they have been always *tacitly admitted*; and only brought into question in the latter, because it is only in the latter that the instruments by which truth is sought, are themselves made subjects of discussion.

But as we have no instruments to apply to inquiries into the mind itself, different from those which we employ in the other sciences, we must be content to use them in the same manner, and trust them equally; otherwise we must abandon the labour.

“All reasoning,” says Dr REID, “must be from first principles, and for first principles no other reason can be given than this, that, by the constitution of our nature, we are under the necessity of assenting to them. Such principles are parts of our constitution, no less than the power of thinking. Reason can neither make them nor destroy them, nor can it do any thing without them. We cannot prove the existence of our minds, nor even of our thoughts and sensations. A historian or a witness can prove nothing, unless it be taken for granted that the memory and the senses may be trusted. A natural philosopher can prove nothing, unless it be taken for granted, that the course of nature is uniform, or her laws permanent. That my thoughts and sensations must have a subject which I call myself, is not an opinion got by reasoning, but a natural principle. The belief of it, and the very conception of it, are equally parts

of our constitution. If we are deceived in it, we are deceived by Him that made us, and there is no remedy."

"Deny the evidence of memory as a ground of certain knowledge," says Mr STEWART, "and you destroy the foundations of mathematical science, as completely as if you were to deny the truth of the axioms of EUCLID;" but no man can give a reason for believing in what he remembers, any more than in what he feels.

Those who do not put faith in *any* such fundamental laws of belief as are here mentioned, are thereby disqualified for scientific inquiries of all kinds, equally as they would be by the loss of the faculty of memory, because it is manifestly absurd for any one, who has determined that he will believe nothing, to engage in the pursuit of knowledge.

But those who admit that there are *some* principles which must be believed, for no other reason than that we cannot help believing them, may reasonably inquire, in regard to any individual principle, which commands the general assent of mankind, whether it is really of this kind, or whether the belief reposed in it can be founded on any fallacy.

It is only by careful reflection, on the circumstances in which these articles of belief take possession of our minds, that we can judge on this point; but the following have been stated as the most distinctive marks of those principles, which are entitled to be regarded as fundamental laws of human thought.

1. These principles are formed, and in the first instance believed, uniformly, by all men, and in all circumstances, and do not appear to be influenced by any accidents, of situation, habits, or previous associations of individuals.

2. They are of such a nature, that they can neither be attacked nor defended, in any other way than by reference to principles, which are not more universal, and have no other foundation than themselves.

3. Their practical influence is found to extend, even to those who affect to question their authority *.

Judging by these marks, and by carefully attending to the natural, uniform, and irresistible tendency of our own minds, we believe that the following principles, so formed, may be regarded as belonging to the class of fundamental laws of belief.

1. The belief in the existence of the sensations and thoughts which pass through our minds, and in our own existence, as sentient and thinking beings,—or the faith we repose in the Evidence of Consciousness.

2. The belief which we repose in what we remember to have felt or thought, or in the Evidence of Memory, and in our own Identity during the whole time to which our memory extends, which implies the formation of the general idea of Time.

3. The belief, already mentioned, in the external and independent existence of the causes of our sensations, or in the Evidence of Sense, which involves the formation of the general idea of Space †.

* See STEWART'S Elements of the Philosophy of the Human Mind, vol. ii. ch. i. art. 2 & 3.

† The sceptical argument against this universal belief, when

4. The belief in the existence of an Efficient Cause, for the changes that we see take place around us, which implies the formation of the general idea of Power.

Here it is to be observed, that our senses never inform us of any events in nature as being causes of other events, in any other way than by showing that they are immediate and invariable antecedents of these. It is only by experience of the consequences which follow any change, that we learn what consequences to anticipate, when we see the same change again.

But although this be the case, most philosophers

reduced to its simplest terms, appears to be this, That we know nothing of any existences external to our own minds, except by means of those feelings which we call Sensations, and therefore that "the material world, if such there be, must be the express image of our sensations;" but that a sensation is a mental change only, and it is absurd to suppose that any thing can resemble a sensation, except another sensation in the same, or another mind.

The answer given by Dr REID and others to this argument is, that although it is by means of sensations that we acquire our knowledge of external things and their properties, yet that, in point of fact, the notions which our minds are so constituted as uniformly and necessarily to form of these (at least in the case of the primary and most essential qualities of bodies already noticed, p. 241), have *no resemblance whatever* to the sensations, through the intervention of which they are formed; that the material world therefore, as made known to us through our senses, is *not the express image of our sensations*, nor does it resemble them in any particular; and therefore, that although our notions of its nature, and belief in its external existence, cannot be explained, and may be said to involve a *mystery*, as every ultimate fact, whether in physics or metaphysics, does, yet they involve no *absurdity*. The essential point of this answer is not correctly stated by Dr BROWN in his criticism on it.

have thought, that the mere observation of changes in the world around us naturally suggests to the mind, not only the facts of antecedence and consequence, but farther, a general notion or idea, which we express by the term Power; and the notion thus expressed, being truly an attribute of Mind, is considered as the first step in Natural Theology*.

5. The belief in the stability of the Order of Nature, which is necessary to enable us to apply the experience

* That this is a fact in the natural history of the mind is denied by others, and especially by Dr BROWN, who argues that no farther idea is annexed to the term Power, than merely "invariable antecedence," and that the mere observation of the changes of physical events would never suggest the notion of any attribute of mind, that being only suggested, according to him, by the observation of contrivance, or adaptation of means to ends. (Lecture 7.)

But that a general notion, distinct from mere uniformity of sequence, and most correctly expressed by the term Power, does suggest itself to the mind, on the mere observation of physical changes, appears not only to be sufficiently proved by considerations stated by Mr STEWART (Outlines of Moral Physiology, § 257), but to be distinctly admitted by Dr BROWN himself in other parts of his Lectures. Thus, in speculating on what would have been the effect "if the generations of mankind could have existed in a world of darkness, and then the sun had arisen suddenly on the earth," he says it would have been sufficient to show, "that there is a Power *which can create*." "The sudden appearance of the sun would have indicated Power of some sort;" and again, "After a few successions of days and nights, its regularity would *add* to the previous conception of Power some conception of corresponding *order*;" (Lecture 92). This passage, and others to the same purpose, sufficiently demonstrate that the conception of *sudden and striking change* was sufficient to introduce the idea of Power, exactly as commonly understood, even to a mind that had denied the possibility of its introduction in that way.

of the past to the conduct of our lives, or the knowledge of natural phenomena acquired by one person, to the instruction of others. This belief is judged not to be the result of experience, because it may be observed to operate the most strongly in those whose experience is most scanty, and in relation to subjects which are perfectly new to them *. Indeed, several philosophers teach, that our belief in the independent existence of external things, being founded on a *repetition* of sensations, is resolvable into this principle of our nature.

6. Our belief in our own Free Will, involving the general idea of Voluntary Power, in like manner attends a part of those mental changes, which the exercise of sensation excites.

In regard to this, just as in regard to the other principles now stated, it is a fair question, whether there is any reason for thinking that the feeling of voluntary power, which undoubtedly attends certain acts of the mind, can be fallacious. But if no irresistible reason be stated *against* the belief, it is unreasonable and unphilosophical for us to ask, because it is impossible for us to obtain, any other reason *for* the belief, than the fact, that in performing certain of the mental acts, of which we are conscious, we are naturally and uniformly impressed with the conviction, that we may do so or not as we please. If no clear proof be given, that this conviction is erroneous, and that the general notion of free will which it involves is a fallacy, all that we have to do is to state, in the course of our account of the different mental phenomena, what the

* See STEWART'S Elements, vol. ii. chap. i. sect. 3.

circumstances are, in which it uniformly and spontaneously arises in our minds.

What has already been said of Sensation, and of these different acts of Thought, which naturally and inevitably succeed sensation in every individual of sound mind, is sufficient to show that the only *foundation of much of our belief*, and the only *source of much of our knowledge*, is to be found in the *constitution of our own minds*. Not only are the notions that we form of the qualities of external things, which affect our senses, totally different from our sensations themselves, but certain general ideas, which inevitably arise in our minds, in consequence of the exercise of our senses, are at once perceived, when the attention is fairly fixed on them, to have an extent of application far beyond what the senses themselves can ever reach. The simple notion of our own existence, which is sufficiently suggested to our minds by the occurrence of any single sensation, instantly extends to the whole period of which our memory gives us any information. The notion of Power, or Causation, which may be suggested by the observation of a single striking change in the world around us, is immediately judged to be applicable to all changes without exception. The notion of Time is no sooner formed, than it swells in the human mind to Eternity, as surely as the notions of Space and of Number to Infinity.

Even from these simple instances, it appears, how necessary an addition was made to the scholastic maxim “ Nihil in intellectu quod non fuerit prius in

sensu," by the words " Nisi intellectus ipse *," and how extended a meaning we must annex to the word Reflection, if we assent to the doctrine of LOCKE, that all our knowledge is derived from Sensation and Reflection. Although " sensible objects may be the destined medium to awaken the dormant energies of the understanding, yet are these energies themselves no more contained in sense, than the explosion of a cannon in the spark that gave it fire."

It is next to be observed, that many of the mental acts, which are felt as constituting our trains of thought, consist in a certain renewal, or what we call Recollection of past Sensations. The act or state of mind which constitutes such a recollection is felt as much slighter, and much more transient, than the impression formerly made on some one of the senses, but is precisely similar to it. To this act of mind the term Conception is properly restricted.

Farther, this act of mind, transient as it is, always carries along with a conviction, that a precisely similar state formerly existed in consequence of an impression on the senses; and to this *conviction of past existence*, attending the consciousness of the present existence of this or any other mental act, we properly refer when we use the term Recollection, or Memory.

The act of mind, distinguished by these last terms, is so very frequent and important, that it accompanies or immediately succeeds almost all others, and appears, on consideration, to be essential to the formation of our

* LEIBNITZ.

simplest notions of the qualities of objects, and to the other mental acts which immediately result from sensation.

The Conceptions, or renewed images of past sensations, present themselves to the mind in succession, and mingled with other thoughts, but independently of any effort of the will ; the degree of indirect power which the will has over them will be considered afterwards, but it may easily be observed, that no such effort is necessary, in order that conceptions may present themselves in various number and order. And on reflection on such an involuntary succession of images in the mind,—particularly on such as from any cause impress themselves more strongly, and remain longer, than usual,—it is thought by several metaphysicians, that there is a natural tendency of the mind to conceive them as representing external and independent existences, in like manner as sensations do. This tendency is instantly checked, and prevented from leading to a false judgment of the mind, by two circumstances—1. Although each conception is involuntarily presented to the mind, yet we are conscious of a voluntary power either of retaining it, and fixing our attention on it, or of letting it pass off, which naturally leads us to believe, that it has no existence independent of the mind that is conscious of it.—2. The conceptions are continually intermingled with real sensations, dependent on impressions from without, which convey to us a notion, known to be correct, of external and independent existence ; and which we feel to be widely different from the concep-

tions, and often to be incompatible with the external existence of any causes corresponding to these.

That there is a natural tendency to believe in the present external and independent existence of the causes of our conceptions, as well as of our sensations, appears probable from the state of our minds, when many vivid recollections of past sensations, or fancied images closely resembling such recollections, with little interruption either from present sensations or voluntary efforts, are called up by an interesting narrative read or heard; and still more by the state of mind during Sleep, when both the checks stated above to the belief reposed in them, are withdrawn (sensations being little felt, and voluntary efforts suspended), and when the same belief attends conceptions, as attends sensations and perceptions in our waking hours*.

These statements are important as illustrating the formation of delusions in Delirium and Mania, when, in consequence of conceptions (and other acts of thought to be afterwards mentioned) being more vivid, and more lasting than usual, and absorbing the attention more completely, their causes are believed to have a separate and independent existence, just as those of sensations are in the healthy state.

The power or disposition of the mind to form, at any future period, the conception of, *i. e.* to remember, any sensation, or indeed any act of thought, depends very much on the circumstances in which the original impression is made, and especially on the state of the

* See STEWART'S Elements, vol. i. chap. iii.

nervous system at the time : For sensations felt in youth are longer remembered than those which are first felt in advanced life ; and impressions made on the senses during intoxication, during sleep (provided they do not interrupt sleep), or during certain diseased states of the nervous system, although they cause sensation, and even some of the usual effects of sensation, both mental and bodily, are yet very imperfectly, or not at all remembered.

Next, a very important part of the trains of thought, which the exercise of the senses excites in the mind (and which implies indeed an exercise of the different faculties already considered), consists of acts of *Abstraction*, by which we separate from the complex sensation, or conception, corresponding to any individual object, certain of the qualities which that object possesses, and make them distinct objects of attention ; thereby both forming to ourselves general or abstract ideas or notions, and likewise enabling ourselves to form classes or genera of objects. Thus when we compare any two bodies, and observe them to be both black or both white,—compare two animals, and observe them to be both quadrupeds,—two flowers, and observe them to be both fragrant,—we begin to exercise this faculty of abstraction, which enables us to occupy ourselves with the *general relations of things*, and to classify and methodize our knowledge. The nature of this mental operation is perhaps best expressed by the term used by Dr BROWN, the Suggestion of Relations.

It is obvious (on a little reflection), that the general

qualities of objects, expressed by such terms as white, black, tall, short, round, square, &c. and that the general classes of objects, as plant, animal, horse, dog, formed by attention to their respective qualities, have no real external existence, but belong only to the individuals referred to these classes, or invested with these qualities; and it has even been disputed whether any definite notions of these abstract qualities, or of the classes distinguished by means of them, are ever formed in the mind,—some philosophers thinking that it is only by means of the *words* employed to denote such abstract ideas, that we are enabled to make them objects of thought. This is the substance of the metaphysical dispute between Realists, Nominalists, and Conceptualists. But it appears beyond doubt, that the operation of the mind, by which the relations of things are perceived, and by help of which the objects of our knowledge are arranged into classes, is not only independent of language, but is a necessary preliminary to the use of all abstract or general terms*.

* See BROWN's Lectures; Lecture 46 and 47. The following sentences contain a summary of his doctrine on this subject, which is substantially the same as that of various other authors, and appears satisfactory:—"We perceive two or more objects. This is one state of the mind. We are struck with the feeling of their resemblance in certain respects. This is a second state of the mind. We then, thirdly, give a name to these circumstances of felt resemblance,—a name which is of course applied afterwards only where this relation of similarity is felt. It is unquestionably not the name that produces the feeling of resemblance, but the feeling of resemblance which leads to the invention or application of the name; for it would be equally just and philosophical to say, that it is the name of the individual John or William which gives existence to the

It is important to observe how generally, by means of this faculty of mind, and of the general notions already mentioned as immediately succeeding sensation, our thoughts are elevated above individual objects of sense, and occupied about what are called abstract ideas, or classes of objects; and this is well illustrated by the nature of language;—for there is only one class of words (substantive nouns), and only a part of these, which express what is individual; all others denoting either classes of objects, comprising many individuals, or qualities, or events, common to, or contingent upon, many. This, accordingly, is the faculty, the more perfect possession of which appears to furnish the most essential and fundamental distinction between the human intellect and that of the lower animals.

Again, in reflecting on such acts of thought, a farther distinction presents itself; the mind not only forms general notions of the qualities or relations of objects, but likewise perceives and decides on the relations of different objects to one another, or to these abstract ideas of its own formation; as when the separate conceptions of two quadrupeds not only suggest to us the general idea of resemblance, and the general class of quadrupeds, but likewise fix the relation which each of these individuals bears to those general

individual John or William, and that he was nobody, or nothing, till the name was given, as to say that the name Man, which includes both John and William, is that which includes our notion of their resemblance; and that but for the name, we could not have conceived them to have any common properties."

notions; and this is what is strictly meant by the mental faculty or power of Judgment. A succession of individual acts of this kind takes place when we apply our experience of individual sensations to the formation of classes of objects, and to the determination of laws of nature; and again, when we deduce certain conclusions, either from ascertained laws of nature, as in physics, or from arbitrary definitions of our own, as in mathematics.

In exercising this faculty of Judgment, we are guided, or our judgments are determined, partly by the knowledge we have acquired, or the definitions we have laid down, of the subjects on which our thoughts are occupied, and partly by the intuitive principles or laws of belief already mentioned.

All the acts of mind hitherto mentioned, are said to be simply Intellectual; they cannot be strictly called either pleasant or painful; and they prompt to no acts of volition: but other feelings form part, even of our simplest trains of thought, which are at once felt to belong to a different class. Emotions of Pleasure, Pain, Surprise, Fear, Resentment, Curiosity, &c.—feelings which neither admit of nor require definition,—immediately succeed both the excitation of present, and the recollection of past sensations; constitute a great source of enjoyment, and form a part of what are called the Active and Moral Powers or Dispositions of our nature.

The different acts of mind now considered,—the Apprehension or formation in the mind of certain general notions, the Conception and Remembrance of

past sensations, the Abstraction of certain of the qualities of objects from others, so as to form additional general notions, and, by them, classes of individuals; and Judgments of the relations of objects to one another, and to these general notions; and the simple Emotions, pleasing or painful, which several of these operations excite,—are the simplest elements that compose those various trains of thought, which the exercise of our senses excites.

And before going farther, we can pronounce, with confidence, on the inaccuracy of the theory of several French philosophers and physiologists, who resolve all acts of Thought into Sensation,—a theory which, in fact, amounts to nothing more than an extension of the term Sensation to what, in our language, is expressed by the more general term Consciousness. If we were to adopt that extension, we should not only involve ourselves in misapprehensions, but should be obliged afterwards to subdivide the sensations, so as to make them correspond to what we now call the different mental faculties *.

* “ I perceive a hare,” says Dr BROWN, “ and I perceive a sheep: each of these separate states of my mind is a sensation. I cannot attend to them long without comparing them, and perceiving those circumstances of agreement, which lead me to apply to both the term Quadruped. The one state of mind is a consequence of the other state of mind. But this is far from proving the comparison itself, as a subsequent state or phenomenon of mind, to be the *same mental state* as the mere perception of the two animals which preceded it. If the evidence of our consciousness is to be trusted, it is very different; and on what other evidence can the assertion of their sameness be founded?”—“ It is not as being susceptible of mere sensation,

But when our minds are employed for their destined use, either for the acquisition of knowledge, the pursuit of pleasure, or the attainment of any practical purposes, it is plain that not only these different mental acts must take place, but that they must succeed one another in a determinate order, and tend to a definite object; and accordingly, before we can consider the two noblest and most characteristic, but also most complex, of the mental powers, those of Imagination and of Reasoning, by which the conduct of our lives, *i. e.* the general effect resulting from the operations of our minds, is chiefly directed, we must take notice of the laws which appear to regulate the successions of thoughts in our minds.

II. In this respect there is observed a much greater difference among individuals, or in the same individuals at different times, than in regard to the nature of the mental acts. There are certain laws as to the succession of thoughts, which are imposed by nature on the minds of all; and besides, there is a certain power which we feel that we can exert voluntarily on our own minds.

1. The rapidity with which all the component parts of the train of thought pass through the mind,

but as being susceptible of *more than mere sensation*, that the mind is able to compare its sensations with one another. We may see, and certainly do see, objects together, without forming the same comparison, which could not be the case if the mere coexistence of the two perceptions constituted or involved the comparison itself."—(Lect. 33.) See also STEWART'S Philosophical Essays, Essay i. ch. 3 & 4, and Essay iii.

is very various in different persons ; different in youth and age ; perhaps generally different in women and men. And there is a still more striking difference between individuals, as to the length of time, during which certain peculiar objects of thought dwell on their minds, and the degree of attention they excite. Thus some persons are strongly impressed by differences of colour, some of forms, some of countenances ; the minds of some dwell habitually on certain abstractions, such as numbers, or mathematical figures ; those of others on certain of the properties of external objects ; those of others on the words by which thoughts are expressed, &c. The memory of all subjects of thought depends very much on the length of time that they have occupied the mind ; and therefore the subsequent recollections, and the usual reflections, of different minds, will necessarily depend very much on the peculiarities of this disposition of Involuntary Attention. The striking differences of individuals, in this respect, are well illustrated in the writings of GALL and SPURZHEIM, and their followers.

2. In the same person, at different times, there is also great variety as to the rapidity with which different thoughts succeed one another, and as to the intensity of mental attention which is fixed upon them ; sometimes from physical and sometimes from moral causes. The effect of any cause accelerating the circulation in the brain, in a degree consistent with health, is to increase, for a time, the rapidity and the energy of the mental acts ; and the same is often remarkably seen in the stage of greatest vascular excitement, in febrile and inflammatory diseases. The

effect of every emotion or moral feeling, which blends itself with any mental act, is to modify the rapidity of the train of thought at the time; sometimes to quicken it, as in the case of joy; sometimes more remarkably to retard it, and keep the same image or idea long before the mind, as in sorrow; but always to give additional intensity to the involuntary disposition of the mind, to attend to any such act, as is often shown, both by the long and vivid subsequent recollection of such thoughts, and by the slight degree of attention which any object of sense presented during the continuance of the emotion receives, and the very short period to which the power of recollecting it extends.

3. It would appear that the mind is truly "incapable of attending at one and the same instant to objects to which it can attend separately;" although the length of time during which a single object of thought remains before the mind is often so inconceivably short, as to deceive us into the belief of its actual coexistence with others*. At all events, when any mental faculty is strongly excited, or the attention strongly fixed on one mental act, any other mental act is imperfectly performed, is hardly an object of attention, and fails of its usual effects. Mental occupations of intense interest, or violent muscular exertion, greatly diminish the intensity and the effect of sensations excited by impressions on the senses. On the other hand, any very intense and uneasy sensation so engrosses the mind, as to disqualify it for

* See STEWART'S Elements, vol. i. ch. 2.

carrying on any continuous train of thought, or exciting any definite succession of muscular efforts. And when two distinct impressions are made about the same time on the senses, the stronger sensation overpowers or obscures the weaker.

This principle is of great importance in the pathology and treatment of disordered states of the mind. But in the healthy state, and when none of the mental acts take place with unusual force, there is frequently a *virtual* coexistence of feelings or thoughts, which, when strictly analyzed, appear widely different from each other.

4. Much attention has been paid to the different bonds of union that exist among our thoughts, or the laws of association according to which they succeed each other. When we reflect on the very various thoughts, which pass through the mind within a short time, we are sometimes quite at a loss to detect any principle to which we can ascribe their succession; nor is it certain that any such connecting principle does always exist; but in general we may observe, that one suggests another, either by reason of *previous Association* in the mind, of *Resemblance*, or of *Contrast* in the objects themselves*. When two

* On this subject Dr BROWN makes a just and acute observation. "All suggestion, as I conceive, if our analysis be sufficiently minute, may be found to depend on *prior coexistence*, or immediate proximity. For this very nice reduction, however, we must take in the influence of *emotions* and other feelings; as when an object suggests an analogous object, by the influence of an emotion or sentiment, which each separately may have produced before, and which is therefore common to both.

events which immediately succeeded one another,—when a cause and its effect,—when the different parts of a complex scene, or the different countenances of an assembly of persons,—when the successive steps of a demonstration, or heads of an argument, already gone through,—present themselves to the mind in succession, it is obvious that they have been suggested by the principle of previous association. And, in proportion as that previous association has been more recent, as it has been more frequent, as it has been less disturbed by other concurrent circumstances, as the thoughts constituting it have been longer and more strongly impressed on the attention of the individual, either from his natural disposition, or from emotions pleasing or painful formerly attending it,—the same succession of thoughts will be more certainly and more perfectly reproduced.

The associating principle of Resemblance often brings together in the mind, not only objects of sense, which have obvious and striking similarities, or many qualities in common, but thoughts and feelings which have less tangible analogies, or which resemble each other chiefly in giving rise to the same emotions; as when warmth and sunshine awaken emotions of joy, when slow deep-toned music excites solemn reflections; or in general, when any object of interest suggests those slighter and more fanciful analogies, which may be traced among the component

But it is very convenient, in illustration of the principle, to avail ourselves of the more striking subdivisions, in which the particular instances of proximity may be arranged."—Lect. 35.

parts of the trains of thought to which the epithets of Sublime and Beautiful are appropriated.

Again, in other cases, the resemblances which serve to associate thoughts with each other are in the words which denote them, not in the objects of thought themselves, as is shown by the fantastic assemblages of thoughts often brought together by rhymes, puns, or alliterations.

Some of the greatest intellectual differences that exist among individuals, turn on the natural tendency of the mind, to these associations or successions of thoughts. In some minds the chief associating principle is merely previous association; and if it be strong, such men are well fitted for practical exertions, varying according as their involuntary attention has been more frequently and longer bestowed on one class of thoughts or another; but they are not fitted for works of genius. In other minds the chief associating principle is resemblance; and according to the kind of resemblance or analogy, which they are most apt to observe, they are fitted for various works of art or of fancy. In all men, when under the influence of strong emotion or passion, as the whole train of thought is more rapid, so the associating principle of analogy becomes (apparently at least) more than usually powerful, and the language used is more metaphorical.

It is according to the strength and endurance of more or fewer of these principles of association, that individuals differ in what is commonly called the fidelity and retentiveness of Memory; and it is by the

failure of more or fewer of them, that those diseased states called general or partial loss of memory are chiefly characterized*.

5. All this applies to the causes which influence, or laws which regulate, the train of thought in the mind, independently of any influence of the Will. The Voluntary power which we may fairly affirm that we are conscious of possessing over the succession of our thoughts, is in all cases *indirect*; because it is plain that to make the effort to call up any particular thought, necessarily implies that it already exists in the mind; but is not the less real or important. "It consists in singling out any one thought that has pre-

* It may seem a needless multiplication of scientific terms to speak of the images of past sensations being retained by Memory, suggested by the Association of Ideas, and called up by Conception; and Dr BROWN thought he had simplified the subject considerably by ranking all these powers under one head as Simple Suggestion. But perhaps this generalization is rather verbal than real. When the sight of any scene in nature recalls another which it resembles, it is true that the mind does no more than pass from one state, which the impression made on the eye has excited, into another state which is the conception of the scene formerly before the senses; but it is equally true, that in this mental change, three distinct principles are illustrated; *first*, the power of the mind to represent again to itself an impression formerly made on it through the senses; *secondly*, its power to retain that impression latent, for a great length of time, and recognise it, when again presented, as having been formerly an object of its attention; and *thirdly*, the efficacy of the law of association by resemblance, to which the recollection, at that moment, is to be ascribed. These are all general facts, as to our mental constitution, which connect themselves with others, and demand separate consideration, and hence the propriety of using three different words to denote them.

sented itself, detaining it at pleasure, and making it a particular object of attention ; whereby we not only stop the succession which would otherwise take place, but frequently, by bringing into view less obvious relations among our ideas, direct the current of our thoughts into a new channel." And if this be done repeatedly, and habitually, in regard to the exercise of our minds on any particular subjects,—so as to strengthen and rivet particular successions of these by the principle of previous association,—we ultimately acquire, indirectly, so great a voluntary power over our thoughts, that it requires a considerable exertion of attention to observe, that the laws of association which enable us to recall any piece of knowledge for which we have occasion, are in reality fixed beyond our own direct control by the constitution of our nature.

Our indirect voluntary power over our thoughts is often aided by our more direct voluntary power over various muscles, whereby we may either command, or prevent, the excitation of sensations, calculated either to confirm, or to break through, those lines of association which we may wish to preserve.

When the various thoughts which pass through the mind are habitually intermingled with Sensations, which occupy a certain degree of attention, and which are themselves either pleasing, or painful, or are calculated to excite any peculiar emotions, both the rapidity of the train of thought, and the kind of mental feelings or operations on which the mind habitually dwells, are very apt to be materially modified ; as we observe when we attend to the peculiarities of

character of persons who are habitually asthmatic ; still more of those habitually dyspeptic ; and to the striking differences of the character of the inhabitants of warm and cold climates ; of mountaineers and the inhabitants of plains ; or of persons habituated to solitude and to society.

When the train of thoughts in the mind is either accelerated or retarded, and particular acts of thought rendered more vivid and engrossing, by accompanying strong emotions, the indirect voluntary power is proportionally diminished ; and this is still more the case when certain of the thoughts acquire an unnatural energy from disease.

Not only the principal varieties of character in individuals, but almost all the changes which the mind undergoes in the progress of life, and almost all those to which it is liable in disease, are most easily understood, when they are considered as depending on alterations of the laws which regulate the duration of thoughts before the mind, and their succession in the mind, rather than of the faculties or powers, of which the individual acts of thought, when analyzed, appear to be composed.

III. It was already said, that the highest and most characteristic faculties of the mind are those of Imagination and of Reasoning ; by the first of which we understand the power whereby the mind voluntarily combines various of its conceptions and abstractions, and forms a visionary creation of its own, differing from any thing that has been presented to the senses ;

and by the second that whereby the mind voluntarily connects together successive acts of Judgment on the relations of things ; and so adapts premises to conclusions in matters of speculation, and adapts means to ends in practice.

It is obvious that the exercise of both these faculties implies (or that they consist in) not only the performance of the simpler acts of understanding already considered, but likewise a certain determinate succession of such acts, regulated in the manner above stated by the will ; and that these complex mental acts may be altered or suspended by any alteration of the principles, by which the succession of thoughts in the mind is determined ; and it is in this way, accordingly, that they are chiefly altered or perverted in disease.

In the conduct of life, it is most generally by an exercise, more or less complicated, and partly voluntary, of the Faculty of Imagination, that we propose to ourselves objects of pursuit ; and then, by an exertion more or less sustained, of the Faculty of Reasoning, that we adapt means to the attainment of these ends.

As the more elementary acts of Thought, Sensations, Conceptions, and the perception of the simpler relations of things, are attended with emotions, pleasing and painful, and sometimes with instinctive propensities, so the more complex acts now in question are attended with what are more strictly called *Desires* ; which are, in general, anticipations of enjoyment, of one kind or another, consequent on the prospects, more or less fanciful, of effects to be obtained

by our exertions, and accompanying the complex mental acts, by which these prospects are to be realized. Thus, the Desire of Pleasure, the Desire of Power, the Desire of Knowledge, the Desire of Esteem, the Desire of Praise, the Desire of Social Intercourse,—attend the acts of Imagination and of Reasoning on the common affairs of life, and bear the same relation to them as the Instinctive propensities do to the Sensations by which they are excited, *i. e.* they constitute the chief Motives to our actions.

Farther, in like manner as the perception of the qualities of material things, and the simpler relations of objects of thought, naturally excite in our minds certain simple ideas, and compel our assent to certain intuitive truths, so the observation or anticipation of certain actions and their effects, naturally excite in our minds the notions of Right or Wrong, Justice and Injustice, which may in like manner be held to be ultimate facts in our constitution, and which, when combined with the consciousness of a certain degree of voluntary power, impose on us the sense of Moral Obligation.

As almost all human actions tend to procure some kind of enjoyment or advantage for the agents, some authors have thought that the simplest and most satisfactory view of this subject is, to suppose that all motives to action resolve themselves into the desire of pleasure; and much has been said to prove, that as the highest and most enduring pleasure is derived from the exercise of virtue, there is nothing adverse to morality in this view of human motives and con-

duct. But the considerations urged on this point by Mr STEWART, seem quite sufficient to prove that this is an excessive simplification ; that we have a sense of Duty, not resolvable into a regard for our own happiness, and which ought to be, and often is, a rule of human conduct *.

We must consider, therefore, the general notions of right and wrong, which present themselves on a view of the effects, or probable effects, of human actions, as an ultimate fact in our mental constitution, or a

* These considerations are,

“ 1. There are in all languages, words equivalent to Duty and Interest, which men have constantly distinguished in their signification. They often coincide in their application, but convey very different ideas.

“ 2. The Emotions excited by the contemplation of what is right or wrong in conduct, are different, both in kind and degree, from those which are produced by a later regard to, or careless disregard of, our own happiness. This is particularly remarkable in the emotions excited by the conduct of others, for few men are perfectly fair judges of their own actions.

“ 3. Although philosophers have shown that a sense of duty, and an *enlightened* regard for our own happiness do, in most instances, give the same direction to our conduct, yet this is a truth by no means obvious to the common sense of mankind, but deduced from a very extensive view of human affairs, and of the remote consequences of human actions. Consequently, the great lessons of morality, which are obvious to the capacity of all mankind, cannot have been suggested to them merely by a regard to their own interests.

“ 4. The same conclusion is very strongly confirmed by the very early period of life, at which judgments on the moral character of actions make their appearance,—long before children can form such a general notion of happiness as can demonstrate the coincidence of duty with self-love, and indeed in the very infancy of reason.”—*Outlines of Moral Philosophy*, § 172.

primary element of human reason, equally as the notions of power, of intuitive truth, &c. ; and which imposes on all persons of sound mind a sense of moral obligation, although many circumstances constantly tend, either to weaken its influence on our conduct, or to mislead us in its application.

This slight sketch of the strictly mental phenomena will at least serve to illustrate the different sets of facts which require consideration under this head,—first, the formation of certain general notions and principles consequent on the exercise of our senses,—next, the recollection of past sensations,—then the perceptions of the relations of things and formation of farther general or abstract notions : these thoughts are not only continually mingled with our sensations, and with the recollections of similar states of the mind in time past, but also with emotions, pleasing or painful ; they succeed each other according to certain tolerably definite laws, but are, to a certain degree, regulated by our own will ; and, under this guidance, they are so combined and directed as to excite desires, and call up moral feelings, and so furnish motives for action ; and at the same time, to determine the kinds of actions, by which the objects thus set before us may be attained.

As we formerly stated the manner in which certain sensations, excited in the mind, throw into action directly, or through the intervention of instinctive propensities, certain nerves, muscles, and other moving parts, essential to respiration and digestion (functions

of such importance to the animal economy, that they are not left to the guidance of reason, but provided for by the surer process of instinct); so we have now taken a general view of the slower and more circuitous process, by which the acts of thought that are excited by sensations, and left to the control of the will of the individual, become occasions of voluntary efforts, and thereby of nervous actions, muscular contractions, and motions of other organs of the body. The movements, whether instinctive or strictly voluntary, thus excited in the system, demand a separate consideration.

We can only go a certain length in determining the parts of the larger masses of the Nervous System contained within the cranium, which furnish the essential conditions to the mental operations now considered; but the following facts on this subject appear to be well ascertained.

1. The parts of the nervous system which attain their highest development in the human species, and may, from that circumstance, be supposed to be especially connected with those mental operations in which the pre-eminence of the human species consists, are, the Convolutions of the Brain and Cerebellum, the Corpus Callosum, Corpora Striata, Thalami, and Tuber Annulare. Those which are least developed in the human species, but are proportioned to each other in the different classes of vertebrated animals, and may therefore be presumed to be chiefly connected with sensations and voluntary motion, and to have less

connection with any strictly intellectual acts, are the Spinal Cord, Corpora Quadrigemina, (called Optic Lobes in many of the lower animals), and Vermiform Processes of the Cerebellum. The Fornix, and Pes Hippocampi attain their highest development in some of the mammalia, but not in man*.

2. Although we commonly give the name of Instinct to all the mental operations of which we see indications in the lower animals, yet it is obvious that many of their actions are guided, not merely by the instinctive propensities which are connected with appetites, but by mental operations similar, in some respects, to those of human intellect. In particular, it is obvious, that sensations are distinctly recollected; that emotions (as those of fear and joy) attend them, both when first excited, and when afterwards reproduced; that these mental acts are associated, and called up in successive trains; and even that some of the simpler relations of things are perceived; so that a certain degree of contrivance (implying some exertion of a faculty of reasoning), may be practised; although it is plain that their intellect is very little adapted for forming, or dwelling upon, most general or abstract notions.

Now, it has been shown, by the experiments of FLOURENS, MAGENDIE, and others, that the indications of such mental operations are not diminished by cutting off the cerebellum, in the animals that survive the operation; but that they are almost entirely suppressed, particularly in birds, by cutting off

* See SERRES, *Anat. Comparée du Cerveau*.

the cerebral lobes, which appear to correspond to the great mass of the hemispheres and convolutions of the brain ; particularly in the leading circumstance of the medullary fibres from the spinal cord expanding and terminating in them. An animal thus mutilated may live long, and is capable of sensation, and of the instinctive actions most directly linked with sensations ; swallows what is put in its mouth ; moves its legs when irritated, and its wings when thrown into air ; but, when not excited by any impression on the senses, appears in a state of stupor ; gives no signs of recollection, even of sensations just felt, nor of such emotions as sensations were wont to excite ; and cannot seek its food, nor even avoid obstacles thrown in its way.

Hence it would appear, that such of the strictly mental faculties above described, as these animals possess, and particularly that Memory, or the Association of thoughts, are dependent chiefly or entirely on this portion of the contents of the cranium ; which, accordingly, is the most material part of what is found peculiarly developed in man *.

3. Injuries confined to the hemispheres of the brain have also appeared very generally in the experiments of FLOURENS, BOUILLAUD †, and others, to impair the indications of the strictly mental phenomena ; but no distinct evidence has been adduced from experi-

* See particularly CUVIER's Report to the Institute on the Experiments of FLOURENS, in the *Recherches Physiologiques* of this author, and in the *Journal de Physiologie*, t. ii.

† *Journal de Physiologie*, t. x.

ments, of any one class of these phenomena being more affected by injury of one part of the hemispheres of the brain than another.

Many persons who have given attention to this subject since the first publications of GALL and SPURZHEIM, have agreed with these authors in thinking, that sufficient evidence of the appropriation of different parts of the contents of the cranium, to different mental acts, may be obtained by comparing the heads of individual persons, whose characters and dispositions are known ; and observing such relative proportions of the different parts of the skull to one another, and such prominences or depressions on the skull, as they consider to be sufficient to indicate the comparative size of different portions of the brain and cerebellum in these persons.

The object of this inquiry appears to be quite philosophical, and was accordingly long ago recommended by LORD BACON*. There is nothing improbable, nor in the smallest degree at variance with the principles formerly stated (p. 151, &c.), as to the essential distinction between Mind and Matter, in the supposition, that as (by the admission of all) the whole nervous system furnishes the conditions, necessary to the manifestation of the whole mental phenomena, in this state of our existence,—so any one portion of the nervous system may furnish the conditions, necessary to the manifestation of any one part of these phenomena. And it is also possible, that the different portions of the brain may be appropriated, as the phrenologists

* De Augmentis Scientiarum, Lib. 4. C. 1.

in most instances suppose, to the exercise of the faculties on particular subjects, or particular classes of objects, rather than to such differences among the acts of thought themselves, as have chiefly attracted the attention of metaphysicians.

But when it is considered, *first*, That there must necessarily be great want of precision, both in the physical and metaphysical part of many of the observations made in this way; *secondly*, That sources of fallacy exist in the inference as to the form or size of the brain, from inspection of the skull, particularly in the neighbourhood of the frontal sinuses, and of the cerebellum, which seem sufficient to vitiate some of the conclusions which these authors have regarded as the best established; and *thirdly*, That observations made in this way, by different competent observers, have given, in different instances, very discordant results;—it may safely be inferred, that very little reliance can be placed on conclusions drawn from such comparisons, unless these are confirmed from other sources. And it does not appear, on examination of the results either of experiments on the brains of animals, or of pathological observations on the human body, that any conclusions favourable to the phrenological division of the functions of the different parts of the brain, can be deduced from them.

On the whole, the only point ascertained is, the general appropriation of the great mass of the hemispheres of the brain proper, to the acts of thought; which is by no means peculiar to, and does not derive its chief support from, the writings of phrenologists.

The very same kinds of alteration of the mental faculties have been often observed, from disease or injury of very different portions of the brain; and again, large and various portions of the hemispheres of the brain have been found, in other cases, manifestly injured, or even destroyed, by disease, without perceptible alteration of the mental faculties, almost to the moment of death *. Experiments and pathological observations would seem to indicate, therefore, that the manifestation of these mental phenomena depends, not so much on the mere presence of any particular quantities of the nervous matter of the hemispheres, or the forms which it presents, as on some other conditions in that nervous matter †; and whether these are, in any respect, different from the general conditions, formerly stated as necessary to the nervous actions in all parts of the system, is still uncertain.

* See, for example, a case recorded by Dr ABERCROMBIE, (*Pathology of the Brain and Spinal Cord*, Case 89,) where the patient appeared in full possession of her faculties, mental and bodily, a few hours before death; and, on dissection, nearly the whole of one of the hemispheres was in a state of complete softening.

† FLOURENS' conclusions are, "Qu'une portion assez restreinte mais déterminée de ces organes (lobes cérébraux) suffit au plein et entier exercice de leurs fonctions;" and again, "Les perceptions, les volitions, toutes les facultés intellectuelles et sensitives, occupent concurremment et conjointment le même siège dans ces organes."—(*Recherches*, &c. p. 161 & 212); and the researches, pathological and experimental, of BOULLAUD and others, do not enable us to modify this conclusion farther than had been previously done by CUVIER, *i. e.* by showing that it does not apply to the mere susceptibility of sensation, and of the instincts most closely linked to sensations.

SECTION XIV.

OF VOLUNTARY AND INSTINCTIVE MOTION.

WE have stated what is known of the conditions, under which the human mind is connected with the body, and is informed of, and affected by, impressions made on the body by any foreign substance. We have now to consider more particularly the laws, according to which the body is subjected to the control of the mind ; is made to change with the changes, express the feelings, and minister to the wants, of its immaterial inhabitant.

All the mental acts which can be observed to produce, through the intervention of the Nervous System, any decided effect on other organs of the body, may be referred to the heads of Voluntary and Instinctive Efforts (or Volitions and Instincts), Sensations, and Emotions ; and partial illustrations of the effects of all these mental acts on the body have already been stated. The effect of the volitions and instincts is much more striking than that of any other mental acts, but is also much more limited ; being confined to the direct excitation of certain of the muscles of the body, viz. the voluntary muscles, through certain of their nerves, viz. those formerly described as the motor nerves ; while sensations and emotions produce

well marked effects, not only on these muscles, but also on the involuntary muscles, and the secretions.

All the movements which we call either voluntary or instinctive, are essentially characterized by being immediately preceded by the consciousness of a voluntary effort, and likewise attended by a sensation, which gives information of the position and degree of the muscular contraction that is excited. These mental feelings, accompanying such movements, are easily distinguished. In a case of paralysis, or temporary loss of power in a motor nerve, we have the consciousness of effort without the muscular sensation; and in the case of sneezing, or vomiting, from urgent uneasy feelings, we have the latter with hardly any thing of the former.

The contractions which are excited in the voluntary muscles by these mental efforts, acting through the nerves, are much stronger than any that can be produced by direct irritation of the fibres of these muscles, probably because the nervous fibrils penetrate the whole interior of the muscles, and therefore any irritation acting on them reaches the whole of the fibres more completely than one merely applied to their exterior. But the involuntary, or spasmodic contractions of such muscles, which may be excited by physical irritations of the nerves, spinal cord, or medulla oblongata, are stronger than any voluntary contractions.

Many instances illustrating the great strength of voluntary muscular contraction, under certain circumstances, have been recorded. In the dead body the

tendon of a muscle has generally more tenacity than its fibres ; but there are many cases of tendons ruptured, and even some of bones broken (as the patella), or even the humerus, by the vital contraction of muscles attached to them. The muscles of the lower jaw of a man have been known to raise a weight of 300 lb., and the extensors of the back of a delicate girl, in Opisthotonos, to counterbalance a weight of 800 lb.* The disproportion between the size of the muscles, and the force which they can exert, is still greater in some of the lower animals, especially insects.

It was formerly observed, that the involuntary muscles require intervals of relaxation equally as the voluntary do ; but the increasing difficulty of exciting repeated contractions by efforts of which we are conscious, and the uneasy feeling consequent on frequent repetition of muscular sensations, are peculiar to the muscles employed in the function now under our view ; mental efforts being wholly ineffectual, and muscular sensations being hardly felt, in the involuntary muscles.

The actions of the voluntary muscles are habitually more irregular, and their contractions are often continued longer, than those of the involuntary are ; and it is evident, from the variety of positions which the limbs may retain during sleep, that all these muscles can rest in various states of contraction ; which is of great importance, as enabling them to combine in the performance of complex motions. But the amount of

* See HALLER, Elem. Physiol. tom. iv. p. 481.

contraction, of which these muscles are susceptible, is not so great as that which some of the involuntary muscles, such as the bowels, or the bladder, occasionally undergo.

The rapidity with which separate contractions of voluntary muscles may follow each other, both in the human body and in the lower animals, is inconceivable. It has been ascertained that some men can pronounce articulately 1500 letters in a minute, which implies 1500 successive contractions of muscular fibres. If we suppose, with HALLER, a relaxation, of equal duration as the contraction, to be necessary to make the sounds distinct from one another, each of these contractions must have taken place in the 50th part of a second; but even if this condition be not necessary, each contraction must have been willed and accomplished in the 25th part of a second; and during this time, or in the intervals of these volitions, the mind must have been carrying on other trains of thought. According to the calculations of HALLER, a dog, in running, will sometimes exert distinct volitions for the movement of his legs, 200 times in a second.

It was already observed (p. 170) that the strictly Instinctive motions of the voluntary muscles, caused by volitions which instantly and inevitably succeed certain sensations, however complicated they may be, are performed correctly from the first. But when we attend to the manner in which the strictly Voluntary motions, prompted by more complex mental processes, are at first performed in the human species and in

some other animals, we observe, that it is only by repeated trials, and after frequent failures, that we learn how to move the voluntary muscles, so as to accomplish the objects desired. This process of education evidently depends on two principles, *first*, on the Muscular Sensations, which accompany all the contractions that the will excites, and which are remembered, and are the guide to the repetition of the same action; *secondly*, on the mental law of the Suggestion of Thoughts by previous Association, whereby each of these muscular sensations suggests the volition, which had formerly succeeded it, in the performance of any complex action; so that, after some experience, the different volitions necessary to its performance, become associated in trains, which follow one another without fixing the attention, and cannot afterwards be broken without an energetic effort of the will.

In attending to the acts of our own minds in performing any voluntary action which has, by frequent repetition, become *habitual*, we become sensible of the power and the importance of this mental law of Association.

Farther, by such habitual repetition of movements, the muscular organs concerned in them are gradually augmented and strengthened (see p. 18); and thus a gradual increase is effected in the strength, facility, and precision, with which habitual movements are performed.

These habitual movements are ultimately performed with so little effort, interfere so little with other trains of thought, and the volitions prompting them

are so quickly forgotten, that many writers have considered them as becoming truly involuntary. But that this doctrine is quite incorrect appears distinctly from two considerations.

1. That the inconceivably short space of time, in which the different volitions necessary for such habitual movements must take place, and the total want of subsequent recollection of them, furnish no evidence against their existence, is proved by the case adduced by Mr STEWART on this point, of the equilibrist who balances himself on a cord, and, at the same time, two or three rods on different parts of his body*. The frequent, rapid, varied, and nicely regulated movements, by which this must be done, cannot possibly have been associated in any one train, as those in any habitual mechanical operation are,—because they must be regulated by accidents which will vary on each repetition of the experiment; yet they are performed in as short a time, and leave as little traces on the recollection, as those concerned in any such habitual movement.

2. Although “in playing a musical instrument, or in many mechanical operations in the arts, the motions are so rapid, that we find it difficult to say that there could have been a distinct voluntary effort for each, yet these motions cease as soon as the will to move is discontinued, and begin again when it is renewed. This case is most obviously distinct from the motion of the heart or other truly involuntary muscles, in which not only the closest observation can detect no

* Elements, &c., vol. i. chap. ii.

sensation, but the most resolute exertion of the will cannot modify the motion *."

We must be careful, therefore, never to confound those motions which are truly voluntary, however easily they may be performed, and however closely they may have "clung together by association," from those which, by reason of the peculiar endowment of the nerves employed in them, are truly beyond the control of the will. "*Eterna lege separatur Voluntatis imperium ab Irritabilitatis provincia* †."

Inattention to this distinction led STAHL, DARWIN, and other physiologists to think, that the same law of Association, which explains the formation of habitual trains of successive voluntary motions, would likewise explain the constant successive movements of the auricles and ventricles of the heart, and the peristaltic movements of the bowels ‡, and was generally applicable to all muscular contractions without exception; whereas it is in reality a law of mental phenomena only, applicable to those muscular contractions which are excited by mental acts, but not to other muscular contractions.

The distinction of the Instinctive from the strictly Voluntary motions stated at p. 170, is sufficiently illustrated by the complex acts of sucking and deglutition, correctly performed by the new born infant; and by a comparison of these movements with the corresponding actions of other young animals, destined

* REES' Cyclopædia.

† HALLER.

‡ DARWIN'S Zoonomia, vol. i. p. 38, 267, &c.

to procure their nourishment in other ways; but it is difficult to determine what other movements, as seen in the human species, are truly instinctive. Probably, however, not only those movements by which the immediate gratification of the appetites is procured, but those likewise by which we avoid certain injuries immediately threatening us, as in winking, withdrawing the hand from the fire, or throwing forward the arms when we fall,—those by which we move the eyeballs so as to turn the axes of both eyes to an object which arrests our attention,—those by which we close the sphincters, on irritation of the rectum or bladder,—are truly instinctive; by which we mean that these movements are prompted by volitions originally and directly consequent on certain sensations; and are not prompted, like the strictly voluntary motions, by the more circuitous process above described, in which reasoning, imagination, desire, and experience or association, are successively concerned.

At the same time it is to be observed, that these instinctive motions are always preceded by distinct efforts of the will, and are not therefore the direct effects of mere sensation; and in many instances, in the lower animals, they procure no enjoyment, but inconvenience and even suffering, to the animals themselves, although necessary to the preservation of the species*.

The phenomena of these instinctive motions are peculiarly important as evidences of Design in the Universe, because they are precisely analogous to the

* See PALEY's Natural Theology.

phenomena, from which we all uniformly and habitually infer the existence of intelligent minds in other men; they lead directly to the same inference as to Intelligence; and yet we see clearly, and even feel in our own persons, that the intelligence which they imply is not in the individual beings that are endowed with them, but must be ascribed to the higher Power, from which they derive both their mental constitution and their muscular organs.

The following general facts or principles demand attention in regard to the movements, whether instinctive or strictly voluntary, performed by the voluntary muscles of the human body.

1. They appear to be all the effects of muscular *contractions*. Voluntary relaxations are within the power of the mind, and are necessary to various movements, but do not appear, in the human body, to be in any case the cause of voluntary motions, although it is suspected that they are in some other animals*.

2. As the voluntary muscles are intended to move bones, and other solid parts, which are so articulated or connected with one another as to be susceptible of motion only in certain directions, and require considerable force to move them at all, so they have regular forms, and the direction and effect of their contractions are determined by these forms, by their position in the body, and by the other textures, especially the fibrous textures, with which they are connected. But every muscle can contract either partially or com-

* See BECLARD, Anat. Gen. p. 564.

pletely, with various degrees of force, and to various extent, and can combine variously with the contractions of other muscles; and therefore it is impossible, by merely studying the forms of muscles, and their origins and insertions on the skeleton, to understand the whole extent and variety of motions, which these muscles may communicate to the bones, and to the soft parts which the bones support.

3. The word Origin is generally applied to the less moveable extremity of a muscle, and the word Insertion to the more moveable, which is brought towards the other when the muscle contracts; but in some cases, the less moveable extremity of a muscle is fixed by other muscles, and it then acts on its origin, as when the abdominal muscles assist in depressing the trunk of the body, or when the genio-hyoideus and mylo-hyoideus depress the lower jaw.

3. Muscular fibres are generally placed obliquely to the line of direction in which the motion they communicate is to take place, being seldom rectilineal, often radiated, penniform, or compound penniform. From this two consequences necessarily follow, *first*, That they must exert a *greater* force to communicate a given extent of motion; *secondly*, That they will undergo a *less* amount of contraction in communicating that extent of motion, than they would have done if their direction had coincided with their line of action.

Farther, the oblique disposition of the fibres of muscles allows of their tapering form, and of their power being concentrated in narrow tendons, or on

small points, and is therefore frequently important, both to symmetry and to convenience.

5. In studying the action of muscles on bones, and on the parts which these support or inclose, we consider the bone as a lever; the joint at which it is to be moved as the fulcrum; the muscle, acting at its point of insertion, as the power; and the weight of the parts supported by the bone, acting at their centre of gravity, as the weight or resistance, which the lever, moved by the power, has to overcome. And in this view we observe, *first*, that the kind of lever employed in the animal system is generally of the third order, *i. e.* where the power is applied between the fulcrum and weight; *secondly*, that the point where the power acts is generally very near the fulcrum; and *thirdly*, that the line of direction by which the power acts generally makes, in the beginning of the motion at least, a very acute angle with the lever. All these points are illustrated by attending to the insertions of the flexor and extensor muscles of the arm, fore-arm, thigh, and leg. In all these respects, the power of the muscles acts at great disadvantage in regard to the motion to be communicated; and the more so, as the muscles of the limbs are generally bound down by fasciæ, so as not to change their direction so much, and so advantageously, as they otherwise would do, after the motions they cause have commenced.

In all these respects, as well as in the direction of the individual fibres of muscles, the arrangements are such as to economize the *length*, much more than the

strength or power of muscular contractions ; and are, besides, evidently adapted to prevent interference of one part of the body with another, to preserve symmetry of form, and permit elegance of movement.

6. In some instances, however, where the weight or resistance is very great, the lever employed in the animal economy is of the first order ; as when the trunk of the body is either bent or extended on the articulations of the spine, by the abdominal muscles or extensors of the back,—or of the second order, as when the whole weight of the body is thrown on the toes by the elevation of the heel by the *Tendo Achillis* ; and, in some instances, as in this last movement, and in the flexion of the body by the abdominal muscles, both the length of the arm of the lever, by which the muscles act, and the angle at which they act, are much more advantageous than usual. The extension of the body by the muscles of the back, placed longitudinally along the spine, being an action in which the power acts by a very short lever, and often in opposition to gravity, requires a much greater strength of muscle than the flexion of the body does.

7. In performing many even of the most common movements of the human body, a definite combination and succession of contractions, not only of neighbouring muscles, but of distant muscles, associated into groups by their concurrence in these actions only, and by no anatomical relations, is often required. Thus, the projection of the body at each step in running or walking quickly, requires a combined action of the extensors of the thigh, of the leg, and of the

foot, in order that the metatarsal bones may be pressed with due force against the ground ; this must be succeeded by an action of the flexors of all these parts, by which the limb may be raised and brought forward ; and farther, in order that the equilibrium and erect posture may be maintained during these movements, a certain action of the extensors of the back, and certain motions of the arms, are necessary. By much attention, and frequently repeated trials, especially in youth, a great variety of combinations of muscular actions may be formed and associated, exactly in the same manner as those concerned in these common motions.

8. For the performance of most complex actions, not only various muscles, and associated combinations of the actions of these, but a certain adaptation of the form of the skeleton, to the movements thus effected, are essential conditions ; and the circumstances, in the form and disposition of the bones, which are most important for these purposes, are often not obvious on first consideration of the subject. For example, for maintaining the erect attitude of man in all his movements, and at the same time rendering these movements easy and graceful, the following provisions, in the bony fabric, different from what are seen in others of the mammalia, are truly essential ; *first*, That the lower limbs should bear a very unusual proportion to the whole body in length, and their articulating surfaces in breadth ; *secondly*, That the pelvis should be unusually broad, and so hollowed internally as to give room for certain viscera, and through them support to others ; and that

the basis of support which it gives to the trunk of the body in the erect posture, should be farther enlarged by the length of the cervix femoris, which disengages the shaft of the thigh-bone from the hip-joint, and allows the limbs to be widely separated; while the head of the bone, within the acetabulum, being the centre of movement, the angular motion of the pelvis at each successive projection of the lower extremities is small;—*thirdly*, That the shaft of the femur be oblique, and its inner condyle long, as well as its general direction vertical, so that its articulating surface at the knee may be perpendicularly under the pelvis in the erect posture;—*fourthly*, That the whole lower surface of the tarsus, metatarsus and toes, be at right angles to the leg, and rest on the ground in standing, so as to give a broad and firm support to the body;—*fifthly*, That the breadth of the bony fabric of the chest be greater than its depth from the sternum to the spine, whereby the arms are widely separated, and the centre of gravity of the trunk is thrown back;—*sixthly*, That the lumbar vertebræ and sacrum be large and strong, and the vertebral column disposed in a waving line, so that the viscera may be duly lodged and supported, and the centre of gravity be prevented from coming too much forward in the erect posture;—and *lastly*, That the foramen magnum, and condyles of the occipital bone be situated about the middle of the head, and the eyes and mouth be directed forwards, so that the form of the head and face may be adapted to the erect posture. The peculiarities of the forms of the muscles, attached to these

parts in the human species, correspond strictly with those now stated in regard to the bones*.

The particular combinations of contractions of voluntary muscles, and movements effected by them in the other parts of the body, cannot be studied with advantage without the aid of preparations or drawings; but are well explained in the writings of BARCLAY †, MAGENDIE, ARNOTT ‡, and ROULIN §.

One curious department of this subject relates to the manner in which the different modulations of the voice, and different articulate sounds, are effected by voluntary movements of the respiratory muscles, and of the muscles of the Larynx, Velum Pendulum, and Arches of the Palate, Tongue, and Lips, producing and varying sonorous vibrations in the expired air. It is ascertained that the posterior part of the tongue, the velum pendulum, and arches of the palate, as well as the muscles of the larynx (especially of the thyro-arytenoid muscles, moved by the recurrent nerves, and which stretch the ligaments of the glottis), are necessarily concerned in the modulation of the voice ¶. The chief agents in articulation are the lips and anterior part of the tongue.

The general effects of repeated and habitual exer-

* See LAWRENCE'S Lectures on the Physiology and Natural History of Man.

† On Muscular Motion.

‡ Elements of Physics.

§ Journal de Physiologie, t. i. & ii.

¶ See Report, by CUVIER, to the French Institute, on a Memoir by M. BENNATI, 10th May 1830; and a case by RE-NAULD, in Journal Hebdom. t. i. p. 66.

cise of voluntary muscles, on other parts of the animal economy, are of great importance, particularly in the prevention of disease. The following effects undoubtedly result from exercise, habitually taken, but within limits consistent with health.

1. The motion of the blood is habitually accelerated, and the heart excited to increased action, whereby, no doubt, it acquires an increase of strength and even of bulk *.

2. The circulation on the surface of the body is habitually excited, and the excretion there, and probably at the lungs also, increased.

3. The circulation in the muscles that are exerted is particularly excited, and their bulk, as well as strength, gradually increased ; and both in consequence of this effect, and of that last mentioned, a considerable derivation of blood from the capillaries of other parts, especially internal parts, is no doubt effected.

4. The mental efforts requisite for continued and vigorous voluntary exertions, and the different sensations necessarily resulting from them, are incompatible with any continued exercise of the mental faculties on other subjects, and therefore often interrupt, or prevent, such trains of thought as might otherwise have occupied the mind.

* Some experiments of MAGENDIE distinctly prove, that strong muscular exertion, particularly when attended with violent efforts of expiration, implying compression of the great arteries in the thorax and abdomen, forces forward the blood into the great veins rapidly and powerfully, at the same time that the flow along these veins is somewhat retarded by the disordered state of the respiration.

It appeared from facts already stated (p. 167 & 306), that such voluntary efforts as continue to be made by an animal in which the medulla oblongata only remains in the cranium, are still effectual in exciting muscular contraction; but that all indications of those more complex acts of thought,—which precede and cause most of the voluntary efforts by which the muscles are moved,—disappear, at least in the higher animals, after the removal of the higher parts of the nervous system, and especially of the hemispheres of the brain. Hence it may naturally be inferred, that, in most cases of voluntary actions, where the volitions exciting them are consequent on recollections and trains of thought (however short), some physical change is transmitted downwards, from the upper portions of the brain or cerebellum, to the medulla oblongata, and excites the peculiar action there, by which the voluntary muscles are excited; and it is reasonable to suppose that any such physical change, which these higher portions of the brain or cerebellum thus transmit downwards to the medulla oblongata, may be imitated by a mechanical injury.

Those considerations enable us to understand how it should happen, as many experiments by MAGENDIE and others have shown, that in consequence of sections of different parts of the nervous system within the head, superior to the medulla oblongata, certain definite and combined actions of voluntary muscles are excited; such as apparently indicate, not that the muscles are moved involuntarily, as by irritation of

their own nerves,—but that the will of the animal is constrained so to act, as to excite certain movements only. Phenomena exactly similar are occasionally observed in the course of various diseases of the nervous system.

The most uniform effects of this kind, observed in experiments on animals, have been a movement forwards, when the bands of medullary matter passing forwards through the Corpora Striata, from the crura cerebri into the hemispheres, have been cut through; a movement backwards, when the Cerebellum has been wounded or cut off; and a movement of rotation, to either side, when the bands of medullary matter passing through the Crura Cerebelli, to form great part of the Tuber Annulare, have been divided on that side. And these facts seem to lead to the conclusion, that those acts of thought which prompt the volition to move in these different ways, act on the Medulla Oblongata for that purpose, through these different parts respectively. It is a fact ascertained by FLOURENS, and which must at present be regarded as anomalous, that section of the branches of the seventh nerve contained in the semicircular canals, in birds, produces movements of the head, horizontal or vertical, according to the parts injured, similar to those now mentioned in the trunk and limbs; which abate when the animal is at rest, but constantly recur when it attempts any other motion *.

The loss of the Cerebellum in animals, particularly

* See Ann. des Sciences Naturelles, t. xv.

warm-blooded animals, appears from the experiments of ROLANDO, FLOURENS, and others, to be generally attended by a peculiar effect on voluntary motion. The animals, after this mutilation, provided that compression of the parts of the nervous system which are left is avoided, not only appear capable of sensation, but give all the usual indications of intelligence, and evidently exert volitions which throw many voluntary muscles into action ; but they are unable so to regulate the contractions of their muscles, as to perform any definite voluntary action, excepting only those which are the most strictly instinctive, and the most closely linked with some of their sensations, such as biting and deglutition. All the voluntary movements of the body and limbs are performed in this state, in so irregular a manner, that they are generally ineffective for the purposes which are evidently intended ; and most of the usual complex movements cannot be performed.

This may be supposed to be, either because the injury produces certain permanent uneasy feelings, such as vertigo, which interfere with and confuse the sensations, by which the voluntary movements are regulated ; or because the recollection of muscular sensations, which are the guide to all definite voluntary movements, depends upon the cerebellum, and is lost when it is destroyed, in like manner as the recollection of other sensations and mental acts appears to be lost when the hemispheres of the brain are destroyed*.

* See GIROU de BUZAREINGUES, in *Annales des Sciences Naturelles*, t. xv. p. 52.

This last opinion may be thought to be supported by the fact, that in Man, where a greater number and variety of complex voluntary movements are learned by experience, and are associated in trains by means of the muscular sensations accompanying them, than in any other animals, the lobes of the cerebellum are more developed than in any other; and again, that, in those animals which have, immediately after birth, the power of regulating their voluntary movements for definite objects, with the most precision, the cerebellum is very generally found, at the time of birth, the most developed.

This is all that can be stated, at present, as to the parts of the nervous system which furnish the conditions necessary for the excitation, *first*, of the volitions by which the actions of the voluntary muscles are caused; and *secondly*, of the muscular sensations, by which they are guided. When the volitions take place, it appears from facts already stated, that it is by changes which they effect in the medulla oblongata, spinal cord, and nerves, that they produce the contractions of muscles.

SECTION XIV.

OF THE PHYSICAL EFFECTS OF EMOTIONS AND
SENSATIONS.

THERE is reason to think, not only that all mental acts are attended by some physical changes in the nervous matter itself, but that different mental acts, and particularly any strong efforts of voluntary attention, produce effects in the state of the circulation through the nervous system. But all the well marked effects upon other organs, which can be ascribed to mental causes, may be referred to the heads of Volitions and Instinctive propensities, already considered, of Emotions, and Sensations. The effects of these last involuntary acts of mind, on the body, deserve more attention than they have received from most physiologists. They constitute one important element, which must be taken into account in considering various questions in pathology and therapeutics; and they may serve to give precision to our inquiries, into the physiological uses of those parts of the nervous system, which we have reason to suppose to be concerned in producing them.

The effects which can be distinctly ascribed to mental *Emotions*, are the following.

I. When acting *in full force*, they excite *strictly involuntary* motions of the voluntary muscles; of

which we are conscious, because no contraction of voluntary muscles takes place, in the natural state, without a muscular sensation informing us of its occurrence; but which we do not excite by any effort of our own, and can only control indirectly, either by fixing the attention on some other object,—and thereby superseding the emotion itself,—or else, by voluntarily exciting other muscular contractions, which antagonize those that we wish to conceal.

Of this kind are the complex actions of Laughter and Weeping, from the feeling of the Ridiculous, or from the emotion of Grief, however excited; whether by what is seen, heard, remembered, or imagined; (generally, however, by the aid of short processes of reasoning on these sensations or conceptions); and the slight contractions of the muscles of the face, and often of the body and limbs, by which mental emotions are expressed, and the interpretation of which has the name of Physiognomy. The movements of Sighing from sorrow, and of Yawning from listlessness, although traced to mental emotions, are more directly dependent on certain uneasy sensations.

These movements, as usually performed in the body, may be said to belong to the same class as the instinctive acts, already considered, by which appetites are gratified; and this class of muscular movements, therefore passes, by insensible degrees, into the last mentioned; but when the emotions prompting to them are of a certain intensity and duration, no voluntary efforts can be felt to intervene between them and the actions; and the most energetic efforts of vo-

lition are even ineffectual in exciting motions by which the action may be concealed.

The essential condition to the actions both of laughter and weeping is a long, often interrupted, inspiration, succeeded by several short expirations; the relaxation or ascent of the diaphragm being repeatedly stopped by short contractions of its own fibres, alternating with those of the abdominal muscles: with these movements are combined certain contractions of the muscles of the glottis and fauces, regulating both the escape of the air, and the sonorous vibrations of the air that escapes, from the windpipe; and likewise certain definite contractions of the muscles of the countenance, and of those moving the lower jaw, which give *expression* to the action.

Besides these definite movements, which are nearly confined to the muscles of the face, neck, and chest, there are other contractions of voluntary muscles from mental emotions, which take place either generally over the whole body, or indiscriminately and irregularly in various parts, as in tremors from fear, or in the writhing of the body from the emotion of horror, or in the course of violent fits of laughter or weeping.

Farther, mental emotions of some strength and endurance, have a manifest influence on the energy of the contractions, excited in the usual way, in the voluntary muscles all over the body; some, such as Anger, Hope, Joy, increasing the muscular vigour; while others, such as Grief, Fear, or more correctly Despair, diminish it. There are examples of persons

long paralytic, who have recovered the power over their limbs suddenly, when under the influence of violent emotions*; and there are many instances of great, although temporary, increase of muscular strength, from the influence of military ardour, and still more of religious enthusiasm or fanaticism.

These effects on the strength of contraction of voluntary muscles, cannot be referred simply to the increased or diminished strength of the circulation, which results from the same mental emotions, and will be considered immediately; because they sometimes take place almost instantaneously, and because other agents which affect the heart's action more powerfully, do not add equally to the vigour of the voluntary muscles. Besides, the emotion of fear often quickens and strengthens the heart's action, while it weakens the limbs.

The effect of emotion on voluntary muscular contractions may be supposed to take place chiefly in that part of the process necessary to such contractions, which is confined to the nervous system; but as a similar effect is produced on the actions of the heart, which are not excited through its nerves, we must suppose that a part of the effect is produced on the property of irritability resident in the muscular fibres themselves.

It is to be observed, that this kind of effect of emotions on voluntary muscles is not produced on individual parts only, but generally over the body.

* See ABERCROMBIE, Pathology of the Brain and Spinal Cord, p. 308.

II. The different mental emotions produce well marked effects on the Organic Functions of the body, and especially on the involuntary motions concerned in circulation, by which they are divided into exciting, such as Joy, Hope, &c. and depressing, such as Grief, Fear, &c.; and although these phenomena are too various and complex to be always reducible to distinct heads, yet this distinction may be recognized in most cases.

1. The effects of the exciting emotions or passions are widely different, according as they are of such a kind or degree as to act gently and uniformly for a length of time; or as they act suddenly and violently, and soon subside.

Such emotions as act permanently, and without violent agitation, *e. g.* the emotion of pleasure that attends any occupation which interests and occupies the mind,—the emotion of hope, from the prospect of lasting and rational enjoyments, or of returning health,—the emotion of benevolence, or kindly feeling, which attends the conferring, or that of gratitude, which follows the receiving, of benefits,—even the excitement produced by a certain degree of the feeling of indignation,—when they are of sufficient intensity and duration, and especially when they are strongly contrasted with the previous state of the mind,—have a decided effect on the circulation; which is chiefly observed throughout the capillary system. They cause a slight, but permanent glow on the countenance, which contrasts with the paleness of grief; they quicken the flow of fluids through, or the secretion on, the conjunctiva

and cornea, and give brilliancy to the eye; they perhaps elevate slightly the temperature of the surface, and certainly cause it to be less easily depressed by cold. According to the observations of SANCTORIUS and of BRYAN ROBINSON, they increase the insensible perspiration by the skin; and according to Dr PROUT, they increase the quantity of carbonic acid thrown off at the lungs; they promote the secretions, as is obvious from their influence in increasing the power of digestion, and securing the regular evacuation of the bowels; and favour nutrition, as appears from their being generally found in connexion with increasing bulk of the body; they have a well ascertained effect in protecting the body against the influence, not only of cold, but of malaria and contagion,—therefore against all the most powerful causes of acute disease; they manifestly accelerate the convalescence from acute diseases, and are found very beneficial in various chronic diseases, in which debility is a prominent symptom. In these last instances, the effect of these emotions is to counteract causes which evidently weaken, and to assist other means, particularly the use of nourishing food, and agreeable sensations of warmth, or moderate alternations of temperature, which strengthen the body. On the whole, therefore, it appears that the effect of these emotions is gently and permanently, and often most beneficially, exciting or tonic, on the circulation; and that it is most distinctly observed in the vital actions that take place in the capillary system of vessels;—the heart's action being little affected in most of these cases,—while, in many other instances,

both from mental and physical causes, the heart is manifestly excited, without any of these good effects.

When any of the exciting emotions or passions act more suddenly and violently, their influence is chiefly observed in the heart, and larger arteries, where the blood is moved solely by the impulse of the heart; they cause increased pulsation, heat, and flushing, and a state like temporary fever, followed often by more or less of depression; but not attended by any of the beneficial effects on the secretions and excretions, and nutrition of the body, above remarked. The exciting emotion of anger, by its stimulating effect on the circulation, has often become the cause of dangerous or fatal disease. This effect on the heart's action, implying an increase of its irritability, according to what was formerly stated (p. 14), is more correctly expressed by the term *Stimulant* than *Stimulus*.

The effects of the more sudden and more violent passions are also more *local* than those of the gentler and more continued emotions. Thus the emotion of surprise, especially when attended with fear, excites the heart's action strongly, and thereby causes irregularities in the flow of blood in the larger vessels, and sometimes internal hæmorrhages; while it causes paleness and constriction, instead of flushing, on the surface of the body; and the emotion of shame has a powerful exciting effect on the circulation in the face and neck, without any such effect on other parts, even of the surface. The well known exciting effects of certain emotions on the secretion of the

lachrymal gland ; of others on that of the mammæ ; and of others on that of the testes, are still more partial.

2. The feeling of listlessness or ennui, from want of mental occupation, and the feeling of permanent depression from continued sorrow, disappointment, or hope deferred, produce effects on the circulation, especially in the capillaries, and on the secretions, just the reverse of those ascribed to a permanent feeling of hope or joy ; they make the face pale, the eye dull, the skin cold or easily chilled ; they diminish the amount of perspiration, and the excretion at the lungs, injure the digestion, and generally bind the bowels, and cause the body to decline in flesh and strength ; they favour the effect of cold, contagion, and malaria, in producing acute diseases ; and facilitate the attacks, and often frustrate the cure, of various chronic diseases, of which debility is an essential constituent.

Again, more sudden and violent emotions of grief, fear, or despondency, or more mixed feelings, as those commonly expressed by the terms Horror, Disgust, Vexation, &c. often produce syncope, sometimes fatal syncope ; they have often a peculiar irritating, if not stimulating, effect on other involuntary muscles, the bowels, and bladder. Fear acts peculiarly on the vessels, and perhaps on the fibrous texture, of the skin ; and different passions affect variously and rapidly the secretions of the lachrymal gland, of the mouth, of the kidneys, sometimes of the liver, and more remarkably of the mucous membrane of the

bowels, and probably of the stomach,—and so dispose peculiarly to diseases of the *primæ viæ*.

Farther, various emotions, at the same time that they affect, in these different ways, the organic functions of the body, excite distinct *Sensations*, sometimes pretty general over the body, sometimes confined to the parts principally affected, and which have been distinguished by the name of *Sensations of Emotion*. Thus a peculiar feeling of chilliness attends the constriction of the surface from fear or other mental feelings; and the sensation of nausea, sometimes leading to vomiting, attends, in many persons, those emotions to which we give the name of horror or disgust. Those persons in whom strong mental emotions, and effects consequent on them, in the circulation, and other vital actions of different parts, have been excited by such means as tractors (real or fictitious), and the manipulations of animal magnetism, have generally felt acute sensations in the parts to which their attention has been forcibly directed. These sensations of emotion so uniformly attend the excitation of physical changes in this way, that it may, at least in some instances, be conjectured that it is through their intervention that emotions effect those physical changes; on which supposition, the agency ascribed to this class of mental acts would resolve itself into that of sensations, next to be considered.

This brief outline of the effects of emotions on the different functions of the body, animal and organic, shews that they differ very materially from the effects

of any voluntary acts in the *extent of their operation* over the body, as well as in the variety of parts which they can affect. At the same time, it shews that, extensive as is the operation of these emotions, there are individual organs which each has a special power of affecting ; a fact which is probably as little susceptible of explanation, as the special effects of the causes of our different sensations on the appropriate organs of sense.

It is also important to observe, that the effects of these involuntary acts of mind are much more various in different individuals, than those of instinctive and voluntary efforts,—some persons being more easily affected by one kind of emotion, and others by another,—and some parts or organs of the body being more apt to suffer in one person than in another. In general, women and children are more under the influence of mental emotions than men are ; and all persons are most under their influence at the times when their voluntary muscular powers are the weakest.

III. The effects, in the living body, which may be reasonably ascribed to Sensations, are very similar to, and in some instances identical with, those that we have ascribed to mental emotions.

1. As to their action on the Voluntary muscles,—the effect of the sensation caused by venous blood slowly pervading the lungs, in exciting the complex actions of inspiration and expiration, was fully considered already. The modifications of these movements in Laughter and Weeping, are produced, not only by

emotions, but also, in those in whom the nervous and muscular organs are much under the influence of involuntary mental acts, by the sensation of pain, and by the sensation of tickling, excited in any part of the body.

The long inspiration of Sighing seems to be merely the effect of the sensation in the chest being felt more strongly than usual, in consequence of respiration having been previously performed slowly and imperfectly for some time together, generally on account of some mental emotion, or intense occupation of the mind, having prevented the sensation, which prompts to inspiration, from attracting the usual attention, or producing its usual effect *. Accordingly, it results from various mental acts or affections, besides the feeling of grief. The action of Yawning seems also to result from a bodily sensation of lassitude or general uneasiness, which both succeeds fatigue and results from inactivity of the body and mind ; this last motion differs from the former chiefly in being followed by a longer and more forcible expiration, and in being attended by a definite movement of the muscles depressing the lower jaw, and by a less definite contraction of various other muscles of the trunk and limbs.

The actions of Coughing and Sneezing are among the best examples of complex motions of voluntary muscles, strictly referable to sensations in the mucous membrane of different parts of the air-passages, and over which, when these sensations are in full force, the Will has no direct power. In both there is a

* See DARWIN'S *Zoonomia*, vol. i.

long inspiration, followed by a sudden and forcible expiration, in which all the muscles that pull down the ribs and force up the abdominal viscera are called into action; but in sneezing both these movements are fuller and more sudden than in coughing, or in any voluntary motion of the same muscles. To both it is essential that the glottis be closed by an action of the superior laryngeal nerves, and arytenoid muscles, after the effort of expiration has commenced, and then, that effort continuing, that it be suddenly opened, so as to give a sudden impetus to the current of air driven through the air-passages, sufficient for the expulsion of irritating matters; but in the act of sneezing, it is farther necessary that the current be directed through the nostrils, by the tongue being pressed against the palate, so as to prevent its escape through the mouth.

The spasmodic movement of the diaphragm, called Hiccup, and the actions of Eructation, Regurgitation, or Rumination, and Vomiting, by which different matters, and with different force, are rejected from the stomach, are likewise preceded, and may fairly be said to be caused, by certain sensations. In eructation, all that seems necessary is, a relaxation, longer than usual, of the muscular fibres of the œsophagus, allowing what lies at the cardia to arise to the mouth; but in the others, and especially in Vomiting, it is obvious that repeated and sudden simultaneous contractions of the diaphragm and abdominal muscles take place at the same time with the relaxation of the œsophagus, by which the stomach is strongly compressed, and its contents forcibly expelled. These

contractions, in the case of Vomiting, are always preceded by the peculiar sensation of Nausea, which may be produced in different ways, and is often attended with more or less of faintness, or of vertigo; and as it becomes more intense, they are gradually and repeatedly excited. This sensation is followed also by a sudden and rapid flow of saliva, and generally of sweat; at the moment of vomiting the glottis is shut, and the velum pendulum palati raised and stretched as in deglutition; and the œsophagus assumes an inverted action*.

The experiments of MAGENDIE have distinctly shewn, that in the act of vomiting, any contraction of the stomach itself which occurs, is hardly perceptible either to the sight or touch; that the simultaneous action of the diaphragm and abdominal muscles is sufficient to expel, in the same way, fluids contained in an inanimate sac, placed in the same situation as the stomach; and even that the expulsion of the contents of the stomach could be produced by a strong contraction, either of the diaphragm or of the abdominal muscles, excited by an emetic, when the other of these agents was palsied. At the same time, it is to be observed, that the appearance of bile, after a time, in matters rejected by vomiting, is enough to show that a degree of inverted action of the stomach and duodenum must attend the movement. And it is pretty certain that there is an increased flow of the fluids of the stomach, as well as of the mouth, during vomiting.

It is important to remember, that the sensation of

* BECLARD,—See Dict. de Medecine, Art. Vomissement.

nausea may be excited in very various ways,—by certain substances introduced in any way into the blood,—by certain irritations of the stomach,—by certain impressions on, or diseases of, the brain,—by certain impressions on the nostrils, or the fauces,—by certain diseased states of the heart, bowels, kidneys, uterus, &c. ;—but in all these cases, when it attains a certain intensity and duration, the complex actions of vomiting follow.

The actions of voluntary muscles, by which the evacuation of the Rectum and Bladder is partly effected, were also stated as examples of the effects of peculiar sensations on this kind of muscles. And in other instances, less definite contractions of these muscles are excited, perhaps directly by sensations, as in the writhing of the body from pain, or from tickling the soles of the feet, the general tremors succeeding the sensations in the bladder and urethra which follow the discharge of urine, &c.

2. Various sensations evidently modify, nearly in the same way as emotions do, the action of different Involuntary muscles, which they cannot be said directly to excite to contraction. Thus, the action of the heart is depressed or weakened by the sensation of nausea,—in some persons by certain smells,—and in all persons by the sensation of cold, when of a certain intensity and duration,—and by intense pain of a peculiar character, and resulting from affections of certain parts, as from a blow on the epigastrium or testis, from inflammation of the bowels or kidneys, &c. ; and it is augmented by a grateful sense of heat

after chilling of the surface—by a slighter degree of pain,—by certain smells,—by grateful impressions on the palate and stomach, &c. The sensation of cold applied to one part of the surface often causes constriction of the capillaries, and perhaps of the skin over the whole body; and sometimes acts rapidly on the involuntary motions both of the intestines and bladder.

3. Sensations act equally as emotions, and variously, on different Secretions of the body,—on those of the lachrymal gland,—of the salivary glands,—of the stomach,—of the liver and kidneys,—and more remarkably of the testes.

Those sensations which are pleasing and lasting, and not violent, especially if agreeably varied, appear to have a permanent beneficial effect on the capillary circulation and secretions, similar to that of the gentler exciting emotions; and those which are more keenly felt, like the more violent emotions, affect individual parts peculiarly, but all of them show a much more extended operation over the system than any individual voluntary acts can exert.

Many of the muscular contractions, and other changes, now described as the effects of sensations, have been regarded by most physiologists as results and illustrations of what has been called Sympathy, or Consent of Parts in the animal system, whereby it is supposed that a change in the vital actions of one part of the body becomes the immediate cause of a change in those of another, although the actions of

these parts have no immediate dependence on one another.

Thus, when cold water dashed on the face, or stimulating vapours applied to the nostrils, cause a sudden act of inspiration, it is said that there is a sympathy between the skin of the face and membrane of the nose, and the diaphragm and intercostal muscles; when nausea and vomiting are produced by various changes in, or impressions on, the brain, nose, fauces, bowels, kidneys, uterus, &c., many physiologists have been satisfied with saying, that there is evidence of sympathies between these parts and the stomach; and again, when nausea and vomiting have abated on certain changes being induced on the skin (as by the breaking out of a sweat, or appearance of an eruption) it has been said that this is an indication of a sympathy between the stomach and skin. So also when grateful food, or stimulating liquors taken into the stomach suddenly, excite the action of the heart, it is said that the heart sympathizes with the stomach.

It is of great importance to possess as accurate information as possible as to the nature of the connexion between different parts of the body, to which this name has been given; because, when we attend to the manner in which various diseases are excited by their external causes,—to the manner in which different morbid changes succeed one another in the course of diseases,—and to the manner in which different remedies appear to influence the body,—we find that these changes are often more analogous to the phenomena usually called sympathetic, than to any others

which the healthy body presents; and frequent reference is accordingly made to the principle of Sympathy in medical writings.

The subject of Sympathetic *Sensations* was already sufficiently discussed (p. 268, *et seq.*); and it is with those *actions* only, of certain parts of the body, which are produced, as is usually said, sympathetically, or by reason of a sympathy with other parts, that we are here concerned.

Now, the following considerations seem sufficient to prove that the doctrine maintained as to this description of facts by WHYTT and MONRO*, and acquiesced in by HALLER, is correct,—that the immediate cause of such changes as those above mentioned (p. 341, *et seq.* and 346), is truly, as we have stated, a mental Sensation, which always intervenes between the impression produced in the one part, and the change which follows in the other (or perhaps more correctly, is some action in the nervous system which is attended with, and makes itself known by, a sensation); and that the two parts sympathize with one another *only in so far* as the sensation which affects the one, is excitable by an impression on the other.

1. That the cause assigned, in this explanation of what are called Sympathetic Actions, is adequate to the effect ascribed to it, is sufficiently obvious from the fact, that the changes in voluntary muscles, in involuntary muscles, and in secretions, thus ascribed to sensations, are not only closely analogous to, but in several instances identical with, those which are

* See WHYTT's Observations on the Sympathy of the Nerves, and MONRO's Treatise on the Nervous System.

allowed on all hands to be excited by emotions ; which are mental acts bearing a close resemblance to sensations, and very generally attended or followed by sensations. Thus weeping and laughter may be excited in the irritable constitution of a child, as surely by a blow on the face, or by tickling the sole of the foot, as by any mental emotion ; and when so excited, furnish as good evidence of sympathy between these parts and the respiratory muscles, as exists to prove a sympathy between the nose and diaphragm.

2. All such phenomena as we here ascribe to sensation, coexist in the animal system only with indications of sensation. Movements may be excited in muscles, by irritation of their own fibres, or the nerves entering these, for some time after animal life is extinct ; but after the indications of sensation have ceased, no movements of the diaphragm result from irritation of the nose, fauces, trachea, &c. similar to those which were so readily excited by irritation of these parts while sensibility remained ; and the different changes usually called sympathetic, are slowly and imperfectly effected whenever sensibility is much diminished, as in the different comatose diseases.

3. In various instances, the sensations, which we have regarded as the causes of changes usually called sympathetic, may be excited by impressions made on *different* and distant parts of the body ; and the actions which succeed them, in these different cases, are *the same* ; which proves that these actions follow, not the irritation of any particular organ, but the excitation of a particular sensation. This is illustrated by the very various modes, in which the sensation of

nausea, and the complex effects succeeding it, may be excited; by the excitation of laughter, by tickling very distant parts of the surface; by the influence of a sudden and intense sensation of cold,—in whatever part of the surface it may have been excited,—on the respiratory muscles, on the heart, and on the capillaries of the skin.

4. Conversely, when different impressions, made on *the same* part of the body, excite *different* sensations, even although it may be certain that they are felt through the medium of the same nerve, they are *not* followed by the same action. Thus of many sensations felt through the first nerve, very few only are followed by any diminution of the heart's action, or by retching; tickling the fauces with a feather excites retching, but no such effect results from firm pressure against the fauces, nor from their painful inflammation. Certain sensations in the nostrils and face, felt through the fifth nerve, are followed by full inspiration; but no such effect results from cutting, burning, or bruising these parts; certain sensations in the abdomen, as those excited by a blow on the epigastrium, or inflammation of the ileum, are followed by uniform depression of the heart's action; but many other sensations are strongly felt in the same parts, without any such effect resulting.

5. It was already stated (p. 294), that when the mind is much engrossed, either by previous sensations, or by interesting trains of thought, any impressions on the organs of sense are transiently and imperfectly felt; and in these circumstances it is observed, that

the effects usually following such impressions in distant parts, and ascribed to sympathy, are either suspended or imperfectly produced; which is farther proof that the intervention of the sensation is essential to their production. Thus the actions of hiccupping, coughing, sneezing, even vomiting, or laughter from tickling,—when the sensations preceding them have not been very intense,—have often been observed to be arrested or prevented by sudden and lively impressions on other sensual organs, or by the excitement of intense mental interest on other subjects; and the same is true of the effects of cold applied to the surface, on the heart, or on the capillary circulation.

6. The remedies which have been found most effectual in stopping or preventing the actions usually called sympathetic, when in excess, are either such as make strong and new impressions on the organs of sense, and thereby, on the principle just stated, diminish the effect of sensations already existing; or else such as blunt the sensibility in general, and therefore must be expected to diminish all effects of sensation.

7. Another peculiarity of such actions, denoting their origin in affections of mind is, that they are remarkably obedient to the law of habit, being more easily excited where they have repeatedly and recently taken place, as is seen particularly in coughing, sneezing, and vomiting;—the short train of mental acts, consisting chiefly of sensations, but often including slight voluntary or instinctive efforts, which precedes any one of these motions, is easily reproduced by association, after a few repetitions.

Thus it appears that when any vital action, or alteration of action, in one part of the body, is said to be the result of Sympathy with another part, the fact is in general more correctly expressed by saying, either that the two parts are affected by some sensation which acts on both alike, or that some sensation, which is the natural cause of the action at the one part, is the natural effect of an impression made on the other. And we cannot go farther than this in explaining such connexions of the living actions of different parts.

Many physiologists have indeed supposed, that what have been called sympathetic actions, may be explained by connexions among the nerves of the sympathizing parts; and it seems to be the opinion of Mr BELL, in regard to the movements of the respiratory muscles (which are so generally and so variously excited in this way)*,—and is also stated more generally, although in a more qualified manner, by Mr MAYO †, —that the circumstance of nerves being connected, not in their course, but at their origin, gives a peculiar tendency in the parts supplied by these nerves to sympathize; or furnishes an explanation of the fact, that a sensation, felt through one of these nerves, excites a muscular movement, or some other change, through the other.

But various considerations, several of which were stated on this subject by WHYTT and MONRO, seem equally conclusive against the supposition of such con-

* Exposition of the Nervous System, pp. 54, 76, 88.

† Outlines of Physiology, 2d edition, p. 343.

nexions in the vital actions of different parts, depending on eonnexions of nerves in their course, or at their roots.

1. We have already seen, and must regard it as a leading fact in regard to actions of this class, that it is *not every impression* made on the sensitive organ concerned in any such case, which is followed by the change in a distant part, but only *those impressions* which excite a particular sensation ;—that other impressions, although felt through the same nerve, if they excite different sensations, have no such effect ;—and again, that impressions on other parts, felt through other nerves, if they excite the same sensation, have the effect. Now, no effect, which is thus variable and occasional, can be ascribed to a cause which is uniform and permanent, such as a eonnexion of nerves, whether in their course or at their roots.

2. Although there are various cases (enumerated by Mr MAYO), where a nerve, certain of the sensations of which are followed by a change in a distant part, arises very close to the nerve of that other part, yet this is by no means a general law. For example, some of the most striking sympathetic actions in the body are those excited in the diaphragm, intercostal muscles, and abdominal muscles, by impressions on the sentient extremities of the fifth and eighth nerves, as in the varied actions of breathing, coughing, sneezing, vomiting. But the phrenic, dorsal, and lumbar nerves, by which these actions are known to be excited, are not so closely connected at their root, with the fifth and eighth nerves, as several

other motor nerves are, which are not affected, or very slightly affected, in these movements. Again, several motor nerves arise nearer to the origin of the olfactory, than the phrenic and dorsal nerves; but it is by these last that vomiting, when produced by smells, must be excited; and the third, fourth, and motor part of the fifth, arise nearer to the origin of the optic nerve than the seventh does; but a portion of this last nerve, moving the orbicularis oculi, is much more surely excited by bright light impressing the retina, than any of those other nerves are.

3. Conversely, there are many instances of nerves closely connected at their origin, the parts supplied by which show no tendency to sympathize. No particular effect is ever seen on the motor part of the fifth nerve, supplying the elevators of the lower jaw, from impressions made on those branches of the sensitive part of the fifth, which supply the nostrils, eye-ball, and forehead, though other and more distant nerves are very easily excited by impressions on these parts. The whole of the spinal nerves are associated at their origin, by arising from the same columns of medullary matter; but when an impression is made, and sensation excited, in one of the sensitive cerebral nerves, that sensation extends its influence along the spinal cord, selecting some of the spinal nerves, which it excites, simultaneously or alternately, in the movement to be produced, and *passing over* others, which have just the same connexion with the part where the impression was made.

We conclude, therefore, on the whole, that the

actions or changes usually called sympathetic, whether in voluntary muscles, involuntary muscles, or secretions, are, in general, effects of sensations; and that sensations have a much more extended influence along the spinal cord and nerves, in exciting such changes, than any single voluntary efforts have; but that no anatomical reason can be given for the fact, that each of these sensations acts upon certain nerves only*.

The peculiar effect of certain sensations on individual muscles, or individual organs, is often very troublesome, or even dangerous, and tends to no beneficial effect, in disease; *e. g.* in the case of coughing from incipient inflammation of the bronchiæ, tenesmus from inflammation of the rectum, faintness from inflammation of the stomach or small intestines; but a final cause for the peculiar effect of each sensation, in the healthy state, may in general be easily traced; and we should suffer much more from the want of the connexions, thus established among the actions of our different organs, than we do from their occasionally inconvenient operation.

Some general observations remain to be made on the involuntary agency of mind on body, in the animal frame.

I. It is a curious fact, that the changes thus produced in one individual, are instinctively interpreted by others. It is plain, that the effects of sensation

* For farther illustration of this subject, see a paper on the Physiological Principle of Sympathy, by the Author, in Edinburgh Medico-Chirurgical Transactions.

and of emotion, on the countenance, on the respiratory muscles, on the attitudes and gestures, are no sooner seen than they convey to the spectator a notion of the mental state of the person experiencing them; and several reasons may be given for thinking that this interpretation is not the result of experience.

1. These signs of mental affections are evidently very early understood by young children; sooner than any fixed associations can be supposed to have been formed, by experience, of their connexion with any particular modes of conduct.

2. These *natural signs* of strongly felt emotions or sensations affect us both more quickly and more powerfully, than the expression of them by words, or other *artificial signs* does; which would not have been the case if both modes of expression had owed their significance only to experience, and therefore been on the same footing.

3. To one who attends to them minutely, the varying expressions of countenance, manner, and voice, in a person under the influence of strong unaffected feelings, convey *more meaning*, and denote nicer varieties of these feelings, than we have words to express; or than experience can have taught.

The rapidity and precision with which the natural signs of the passions are interpreted, are most strikingly illustrated in observing the effect of theatrical representations, and especially of pantomimes; where it is obvious, that although few individuals acquire the power of correctly imitating the effects of strong emo-

tion or feeling, yet no man has any difficulty in interpreting and appreciating its correct imitation *.

The final cause, or use, of many of the effects of sensation and emotion on the body, particularly of such as show themselves externally, is to be found in this interpretation of them by other men. The provisions of nature, in the constitution of each individual of the human species, are not confined to his own immediate wants ; they extend to his adaptation for social intercourse ; to the relief of his sufferings by the sympathy, and the increase of his enjoyments by the participation of others ; and to the cordial union and co-operation of numbers, in prosecuting objects, and surmounting difficulties, for which the exertions of individuals would be inadequate.

II. This becomes still more obvious when we consider, that along with the instinctive, or at least very rapid, interpretation of the natural signs of Sensation or Emotion, there is more or less of a natural or instinctive disposition to *imitate* these, in the person who interprets and is affected by them.

What has been called the Principle or Desire of Imitation is exemplified strongly, and has been considered by some as exemplified only, in the strictly voluntary actions ; as in the case of children, who “ copy the voices of their companions, their tones, accents, and modes of pronunciation ; and learn, in-

* See STEWART'S Elements, vol. iii.

sensibly, to model their habits, on the appearance and manners of those with whom they are habitually conversant." But it is even more strongly marked, at least in constitutions very susceptible of changes of this kind, in regard to many phenomena which come under the head of Involuntary Agency of mind on body; as in the case of yawning, laughing, weeping, even nausea and vomiting, fainting, involuntary motions of the face and eyes, and involuntary contractions of the body and limbs in different spasmodic diseases. The spectator, in these cases, first interprets these movements as an expression of some emotion or feeling in the actor, and then assumes somewhat of the same feeling himself; and then this assumed feeling produces somewhat of its natural effect on his own system. In some cases, the emotions arising from the sight of the expression, or even the sure anticipation, of suffering in another, produce likewise slight but distinct *sensations* in the spectator.

The degree in which the mind of the spectator, in such cases, participates in the feelings of the actor or sufferer, depends on various circumstances, the influence of which is easily understood, and is of real importance in the conduct of life. It depends on the nature of the emotion or feeling expressed; the gentler and more amiable emotions being in general most easily communicated from one person to another, while the rougher and more boisterous passions excite less sympathy when suddenly presented, but if gradually infused into the mind of the spectator, rouse

him to stronger emotions, and often to a more permanent and cordial imitation and aid of the person whose words or actions excite them. It depends on the circumstances in which the expression of emotion or feeling is observed, which are sometimes such as, by suggesting a short and simple process of reasoning, to interest the mind of the spectator strongly, and at other times not. It depends on the susceptibility of impression and of change in the Nervous System,—remarkably different in the two sexes,—and on the character and state of mind of the spectator, especially on the degree in which his mind is open to new impressions, and unembarrassed by previously prevailing thoughts, as in early youth,—or accustomed to various impressions, and preoccupied by habitual attention to other objects, as in more advanced life. And it depends also, very remarkably, on the number of spectators. For when the emotion which agitates an individual, is reflected from the countenances, and expressed by the voices, of many around him, its intensity, and the tendency it gives to imitation of those by whom it is expressed, are naturally multiplied by the extended operation of this principle*.

Hence the most striking examples of the natural interpretation, and instinctive imitation, of the effects of violent emotion or passion, are always seen in large assemblies of men; and the excitement of courage, or the diffusion of panic, among soldiers, the extremes

* See SMITH'S Theory of Moral Sentiments.

of party violence, the absurdities of religious fanaticism, the propagation of various disorders of the nervous system in schools, prisons, or hospitals,—are all illustrations of the principles now stated.

When we compare the evils with the benefits which we derive from the disposition, existing more or less in every individual of our species, to sympathize with, and participate in, the feelings of those around him, we can have no doubt that the benefits infinitely outweigh the evils. But it is important to be aware of, and prepared for both.

III. We cannot give an opinion with confidence as to the parts of the Nervous System that are chiefly concerned in the Involuntary agency of Mind on the human body ; but the following general facts, in connexion with that subject, seem to be tolerably well ascertained, and to demand attention.

1. Several organs belonging to the department of *organic* life, which are much influenced by mental emotions and sensations—the heart, the bowels, the capillary arteries, the secreting organs—are chiefly supplied with nerves from the ganglia and plexuses of the sympathetic nerve. And it is remarkable that the veins, in which no influence of these mental acts is discernible, have in general no such nerves*.

* See BECLARD, Anat. Gen. p. 688. In what follows, the term Ganglionic nerves is applied only to those which have much connexion with the ganglia of the sympathetic nerve. There has been no probable conjecture as to the use of the ganglia on the posterior roots of the symmetrical spinal nerves.

2. Those *voluntary* muscles, which are peculiarly influenced by involuntary acts of mind, may be stated to have in general either more ganglionic nerves, or more nerves of the irregular system of Mr BELL (see p. 130), which “connect the divisions of the frame,”—than those voluntary muscles have, which are little under the influence of such mental acts. This appears on comparing generally the nerves supplying those muscles of the face and neck, which are most under this influence, and almost all those of the trunk of the body,—with other muscles of the head, and with the muscles of the extremities.

3. Those muscles, or other organs, which have many of their nerves from the ganglia of the sympathetic, and plexuses connected with them, are thereby (in consequence of the intimate union of very numerous nervous fibrils in these ganglia and plexuses), connected pretty uniformly with the *whole extent* of the cerebro-spinal axis.

4. In several instances, individual nerves which supply muscles notoriously much under the influence of sensations and emotions, are strikingly contrasted with those that supply muscles simply voluntary,—in having a *more extensive* connexion with other nerves, and thereby with an extended surface of the spinal cord; as is obvious on comparing the ciliary nerves coming from the ophthalmic ganglion, and moving the iris, with other nerves of the muscles of the eyeball; the portio dura of the seventh nerve, moving the muscles of the face, with the smaller por-

tion of the fifth, moving the elevators of the jaw ; and these again with the nerves supplying the muscles of the fauces, and the depressors of the jaw ; and the spinal accessory nerve, which, according to experiments by Mr BELL, appears to be the one which moves the sterno-mastoid and trapezius muscles in the respiratory acts, with other nerves supplying muscles in the neck.

5. In some instances, voluntary muscles, having nerves which, through the plexuses and ganglia, connect them extensively with the spinal cord, have been observed to move *under the influence of sensations*, when, in consequence of partial disease of the brain, they were *palsied to voluntary efforts* *.

6. It has been already observed, that from the experiments of LE GALLOIS, WILSON PHILIP, and FLOURENS, it appears that the heart and the capillary vessels, and perhaps other parts concerned in organic life, are influenced by physical impressions made on any *large portions* of the brain and spinal cord, but not directly by injuries, however violent, confined to any very small portions of these organs.

7. It appears from facts already stated (see p. 340 and 345), that sensations and emotions must operate *more extensively* over the nervous system than volitions do, because they throw into action simultaneously

* See BELL's Exposition of the Nervous System, p. 212, and Case by Dr ABERCROMBIE, in BELL's Appendix to Papers on the Nerves, p. 120. Several examples of the same kind, in different parts of the body, have occurred to myself.

very distant muscles, or affect simultaneously distant secreting organs ; and some of them affect simultaneously the whole of the voluntary muscles, and the whole of the small capillaries on the surface of the body.

The general conclusion to which these facts appear manifestly to point is, that when sensations or emotions are strongly felt, they excite changes which extend throughout the whole of the cerebro-spinal axis ; and that those parts which are intended to be peculiarly influenced by these mental affections, are connected, by ganglionic or irregular nerves, with the whole extent of the spinal cord, in order that they may be brought fully under the influence of these changes.

It has been already said, that no reason can be given for the fact, that each sensation or emotion acts especially on certain organs, and therefore through certain nerves ; but if it be true that each of these mental acts extends its influence through the whole spinal cord, there is an obvious reason why every nerve intended to be especially affected by any one of them, should gather roots from every part of the spinal cord ; for which the arrangement of the gauglionic nerves provides.

It is commonly said, that the ganglionic nerves are intended to *preside over* the involuntary motions, and organic functions in general ; but this language is very vague, because no distinct intimation is given of the precise meaning annexed to the term *preside*. But if we suppose, that the object of these nerves is to bring these functions, and the functions of many

voluntary muscles also, *under the dominion of involuntary acts of mind*, we shall propose a definite theory, and one which the facts now stated appear strongly to support.

It must be admitted, however, that this speculation is attended with difficulties, and can only be stated at present as a probable approximation to the truth.

SECTION XVI.

OF SLEEP.

IT was formerly observed, that the alternations of the condition of the functions of the nervous system in sleep and waking, bear so great an analogy to the alternations of rest and motion in living muscles, as to favour the supposition of some active changes, and probably movements, continually taking place in the nervous matter, in the state of waking, which either cease or undergo a change in sleep; and we cannot doubt that some physical change in the nervous system attends the transition from the one of these states to the other. But these, like all other changes in the nervous system, corresponding to the natural changes of the Animal Functions, are known to us only by their effects or accompaniments; so that all we can do, in treating of this subject, is to state what has been observed of the conditions which essentially characterize sleep, of the circumstances in which it naturally occurs, and of those which favour or impede its occurrence. The following are the most important facts that have been observed on this subject.

1. Natural sleep is essentially characterized by the change that takes place in the Animal Functions during it, and especially by the Suspension of all Voluntary Power, not only of that habitually exerted over

the voluntary muscles, but also of that exercised over the trains of thought in the mind (see p. 298). The power of sensation is not suspended; respiration, dependent on sensation, continues; instinctive movements of the limbs, consequent on a constrained posture, take place; any unusual impressions on the senses are felt, and even subsequently remembered; and any strong, sudden impressions are so effectual as to interrupt sleep. But all sensations are blunted; respiration consequently becomes slower and fuller; slight impressions on the senses fail of their wonted effect; no effort of voluntary attention to any of these impressions is observed; and, if we attend as carefully as possible to the state of our minds when sleep is approaching, we observe that we are gradually losing the power of fixing our attention on, and detaining before our minds, any particular object of thought; and that, in proportion as we do so, the images of external things, which pass before our minds, assume the character of reality*.

2. The organic functions go on during sleep, but are differently affected in different parts of the body. The actions of digestion and assimilation are apparently promoted by it; perhaps chiefly because the exercise of the limbs, and of the senses, which continually promote, during waking, the circulation towards the surface of the body, and so retard these internal actions, is suspended. In the hot climates, where the effect of exertion to promote the circulation on the surface is greater than in cold, sleep, after the

* See STEWART'S Elements, Chap. iii. & v.

principal meal, especially if of animal food, seems essential to easy digestion. On the other hand, the action of the heart becomes somewhat slower, and perhaps somewhat weaker, during sleep, probably merely from the want of the stimulating influence of sensations and voluntary exertions. The power of the voluntary muscles, as appears from their condition after waking, is somewhat enfeebled by their inactivity. The perspiration and excretion of the lungs, and the evolution of animal heat, are somewhat diminished. The surface of the body is more easily chilled; and the body becomes more liable than previously to the influence of various causes of disease, the first effect of which is to depress the capillary circulation, especially on the surface.

3. The state of relaxation, or suspension of the animal functions, which constitutes sleep, is, in the healthy state, merely the consequence of the activity of the changes going on in the nervous system during waking; the disposition to it is stronger, as these, within certain limits, have been more numerous and greater; and it is promoted by whatever withdraws the causes, that habitually excite the voluntary activity of the mind;—therefore, by withdrawing all causes of lively sensation, by darkness, by silence or gentle and uniform sounds, by the absence of all pain, or of any strong impressions on the senses of Touch, Taste or Smell, by an agreeable temperature, and by mental tranquillity.

4. The tendency to sleep is evidently promoted, in different cases, by causes which increase the flow

of blood towards the head and its impetus on the brain ; especially if they be not such as to excite at the same time the activity of the mind ; but according to the observations of BLUMENBACH, the turgescence of the vessels of the brain, when that is exposed to view, appears to be diminished during sleep, from which we may infer that the flow of blood through the brain is *retarded*.

5. After sleep the senses are more lively, the train of thought probably more rapid, and all voluntary mental exertions are easier and pleasanter than before ; but the strength of the circulation, especially on the surface of the body, and the full power of the voluntary muscles, appear not to be completely restored until food is taken.

6. In the most profound sleep, the mental acts (excepting only slight sensations, such as those prompting inspiration) are either at a stand, or leave no trace on the memory ; but the state of the mind called Dreaming, which is remembered more or less distinctly after wakening, is very common during perfectly natural sleep ; and is sufficiently characterized by the two circumstances already noticed, that the succession of thought, though often modified by any sensations that may occur, is not regulated by the will, and that the images which pass before the mind are considered as realities.

7. From 6 to 8 hours in the 24 are occupied by sleep, in most adult persons ; but the length of time thus spent, requisite for refreshing the body, is not strictly proportioned to the amount of exertion made

during waking ; and may often be gradually and beneficially abridged by habit, as well as by any desire, strongly impressed on the mind before sleep commences.

The state of imperfect sleep called *Somnambulism*, seems to be characterized by a partial restoration of the power of the will over the voluntary muscles, and over the mental operations, while some part of the mental delusion attending sleep continues ; and especially, by a suspension of some of the principal associations, which were wont to regulate the succession of thoughts ; so that the person does not recall the past thoughts or images which objects presented to him would naturally suggest, and neither talks nor acts as he had been accustomed to do ; although his mind acts with great energy, and sometimes with unusual power, on certain subjects. When he awakens from this state, which he does in general as suddenly as from natural sleep, the usual associations of thoughts in his mind being restored, he retains little or no recollection of what had passed during it. This state has sometimes lasted long, or recurred repeatedly, and in precisely the same form. A similar state of partial and temporary hallucination, with suspension of some of the usual associating principles, sometimes occurs from disease, generally in the course of some of the less violent diseases of the nervous system ;—is sometimes brought on by drinking strong liquors ;—and has often been produced, in certain constitutions, by strong mental emotion, especially when heightened by numbers,

as in the ceremonies of some sects of religious enthusiasts, or by the practices of those who profess Animal Magnetism. Whether in this last case any influence, really emanating from the body of one person, can contribute to the effect upon another, independently of the excitation of a strong mental emotion, is very doubtful*.

There is every reason to believe, that this state of somnambulism, reverie, or extase, depends on some peculiar physical change in the condition in the Nervous System, just as the natural state of sleep, and the more usual forms of delirium do; but none of these states can be ascribed solely, either to alterations of the circulation in the brain, or of the pressure on it, or of its own texture; and as all other changes in the condition of the Nervous System, whether healthy or morbid, are known to us only by their effects, it is in vain to attempt more in regard to this anomalous state of the functions of the brain, than to determine the circumstances in which it occurs, and the phenomena by which it is essentially characterized.

* See the works already mentioned on Animal Magnetism—DARWIN's *Zoonomia*, Art. Reverie; and ABERCROMBIE on the Intellectual Powers, &c. sect. 3. chap. iv.

SECTION XVII.

OF GENERATION.

THIS function is the most complex, and has been called the most mysterious in the animal economy ; because the formation in an animal, of another being, similar to itself, and capable of maintaining a separate existence, is an effect of its vital action, which nothing that we see on examining its structure, or any of its other functions, would have enabled us to anticipate that it would produce. But in every other department, not only of physiology, but of science in general, when we have ascertained the conditions under which a phenomenon takes place, we must admit that its appearance, after all these conditions are fulfilled, is equally inexplicable.

This function is very variously managed in the different orders of living beings. The only condition essential to all cases of generation that have been fully investigated, is the separation of a small portion of the organized frame of a living being previously existing, which portion is capable of subsequently maintaining a separate existence.

But in Man, and in all the higher animals, several distinct subordinate conditions are essential to this purpose, the number of which increases as we ascend in the scale of beings. These are,

1. The formation, in a particular organ, of a germ, or small organized body—to be afterwards developed into a separate animal.

2. The fecundation of this germ, which seems to be always effected by the application to it of a seminal fluid; and implies a distinction of sexes, whether on the same or on distinct individuals.

3. Copulation, which is an essential condition only where it is required that the fecundation should take place, before the germ is detached from the body of the female; *i. e.* in all the mammalia and birds,—in most reptiles,—in some fishes,—and many of the lower tribes of animals.

4. Utero-Gestation, which is essential only where it is necessary, not only that the germ should be impregnated within the body of the female, but that it should draw its nourishment, during a part of its development, from the fluids of the female; *i. e.* in the mammalia, the only true viviparous animals*.

The organs destined for the two first of these purposes,—for the formation and fecundation of the embryo,—although existing from birth, are fitted for their function later than any others (the usual age of puberty in this climate being at from 14 to 16 years); and they become unfit for it again in women at from 45 to 50 years of age, in men at a considerably later and less definite age.

The circumstances in regard to the anatomy of the testes in the adult, which chiefly demand attention here, are their position within the scrotum, and isola-

* See CUVIER, Leçons, &c. t. v.

tion from the surrounding textures by two serous membranes, the tunica albuginea and vaginalis,—their connexion with the rest of the body by the spermatic cord, consisting chiefly of vessels and nerves which descend from high in the abdomen, and by the cremaster muscle surrounding the other parts of the cord, by which the testes may be drawn upwards, and the flow of their secretion along the vasa deferentia probably promoted; their vascular texture, and the very numerous convolutions of their excretory tubes, in the body of the testes and epididymis; and the long and circuitous course of the vasa deferentia arising from them, and passing up the spermatic cords, through the abdominal rings, and by the sides of the bladder and vesiculæ seminales, till they penetrate the prostate gland, and terminate at the origin of the urethra.

The vesicula seminalis appears to consist of a single canal, much convoluted, and which secretes a mucous fluid; and it seems certain that both this fluid, and that of the prostate gland, must be forced out chiefly at the time of the passage of the semen, and be discharged along with it; but although it appears probable, that a reservoir may be provided for the seminal fluid, similar to the gall-bladder for the bile, it has not yet been ascertained whether the vesiculæ seminales, in those animals where they exist, answer this purpose.

When the testes enlarge at puberty, and their secretion is fully formed, the sexual appetite is first felt; and at all subsequent times, the presence of a

quantity of that secretion in the long and convoluted course of the seminal ducts, and perhaps in the vesiculæ, is no doubt one condition essential to its being felt, on the amount of which the degree of its intensity is mainly dependent.

At the same time, the other changes characteristic of puberty take place,—the growth of hair on the organs of generation, in the axillæ, and on the lower part of the face, the enlargement of the larynx, and alteration of the voice, an increased development of the chest and shoulders, as compared with the pelvis, an increased energy of mental disposition, and manifestation of the peculiarities of the male character,—probably connected with an increased development of some portion of the nervous system within the cranium.

These changes are not merely simultaneous with the secretion of semen, but dependent upon it; for they are all prevented from taking place by castration; but whether the sensations and emotions, consequent on the establishment of the secretion, or whether the secreted fluid itself, absorbed into the blood, may be regarded as the stimulus to nutrition in these different parts, is uncertain*.

Although the presence of the secretion of the testes is essential to the existence of the sexual appetite, yet that mental feeling is not immediately excited by any

* The case of the young man born blind and deaf, recorded by Mr STEWART (Transactions of Royal Society of Edinburgh, vol. vii.) appears to favour this last supposition, for all the usual marks of puberty had taken place in him, when he had never shown any marks of sexual desire.

changes in the testes, or seminiferous ducts, and the sensations by which it is accompanied and characterized, are referred to, and are connected with physical changes in, the corpora cavernosa and glans penis. They are on a footing with the sensations of emotion, formerly mentioned ;—as the change in the circulation of these parts is on a footing with the other changes in the circulation, which we formerly referred to mental emotion. But when this feeling has been excited, it has likewise a manifest action on the testes themselves, and greatly promotes the secretion there.

The mental feeling, or emotion of Desire, which has these effects, is probably connected with some portion of the cerebellum ; because it has been often observed to exist in an unnatural degree, in cases of disease or injury of that part ; but we have already seen evidence that the cerebellum is also concerned in very different functions ; and it is very improbable, that the whole of that organ should be devoted to the excitation of this single feeling. It would appear, that the change in the state of the Nervous System, within the head, which attends this feeling, is imitated by the compression of the brain, which results from stagnation of the blood in the jugular veins, because erection, and even emission, very frequently accompany death by strangulation.

The duration and intensity of this mental feeling are remarkably influenced by the mental law formerly noticed, according to which no two mental acts of importance can coexist ; and it is accordingly often ren-

dered ineffectual for its purpose by the concurrence of other feelings; for example, of hypochondriacal apprehensions.

The manner in which the distention of the corpora cavernosa, corpus spongiosum urethræ, and glans penis, is effected, under the influence of this feeling, is still somewhat doubtful. The blood is evidently received into large cells in this texture, but anatomists are not agreed as to whether these cells are truly exterior to the circulation, or merely dilatations of the small vessels. Neither is it certain how the stagnation of blood in the penis is effected; but as it has been found, that in large animals, such as the elephant, the nerves of the penis (which are always large, and originate from several of the sacral nerves, and from the sympathetics), form plexuses in an unusual way about the large veins on its dorsum,—and as MAGENDIE found that ligatures of some of these veins produced a partial distention of the corpora cavernosa,—it is probable that a vital constriction of these veins, determined by an action of the nerves, is its main cause.

The effects of this distention of these parts are,—that the canal of the urethra is straitened and narrowed; that the general direction of the urethra forms a less angle than before with the extreme part of the vasa deferentia, by which the semen enters it, and a greater angle than before with the direction of the orifice of the bladder, by which the urine enters it; and that the form of the whole organ, and the sensibility of the glans in particular, are adapted to their office in the generative function.

The mental feeling which prompts the whole of these changes, heightened by the sensations of these parts in their distended state, ultimately excites both the flow of the semen along the vasa deferentia, and likewise the spasmodic action of the levatores ani and acceleratores urinæ, by which the emission is effected, and which has been vaguely ascribed to a sympathy between these muscles and the urethra.

It is well ascertained by the microscopical observations of LEUWENHOEK, HALLER, SPALLANZANI, PREVOST and DUMAS, MAGENDIE, and many others, that a number of vermiform animalculæ, capable of apparently spontaneous motion, are contained in the seminal fluid of all animals, when these are in a state fit for procreation.

Although the whole of the female organs of generation,—the uterus, and its broad and round ligaments, the Fallopian tubes, vagina, and external parts, as well as the ovaria, are formed from the time of birth, they are more fully developed at the age of puberty, not only simultaneously with, but in consequence of, the development of the ovaria at that time; and the other changes which then take place, and especially the enlargement of the pelvis, growth of the mammæ, establishment of the menstrual discharge, and manifestations of the female character, are also believed to be dependent on the change in the ovaria, none of these having taken place in some cases where these organs were found to be only rudimentary. Whether these changes may be depen-

dent on absorption of something from the ovaries, or whether the sensations and mental feelings connected with the active state of the ovaries are concerned in producing them, is unknown.

The menstrual discharge takes place from the inner surface of the uterus, in the healthy state, every four weeks, lasts about three days, amounts to six or eight ounces, and consists, so far as has been yet ascertained, of blood in a great measure deprived of its fibrin. It is generally preceded and attended, especially about the time of its first establishment, by some degree of pain of the back and abdomen, often of the head, and frequently by dyspeptic, nervous, or febrile symptoms; which abate as it goes on, and gradually subsides; but are aggravated if it is suddenly checked.

As the continuance of this periodical discharge coincides very generally with the time during which women are adapted for childbearing, it seems evidently to be a consequence of the active state of the organs of generation. As it very generally ceases during pregnancy and nursing, it has been often thought to be a succedaneum for the discharges from the system, which take place during these states; and as it has not been ascertained to consist of any thing beyond the usual constituents of the blood, and is manifestly increased, as morbid hæmorrhages are, by causes of general and local plethora, and diminished by means which obviate these, it has been supposed that it is to be regarded merely as a natural hæmorrhage.

But on the other hand, as the effects resulting

from the suppression, especially the sudden suppression, of this discharge, are generally more serious than those which follow the stopping of any simple hæmorrhage, or other evaeuation, of the same amount ; and as such suppression has often been followed by hæmorrhages from parts very little disposed, in general, to such a form of disease,—or by various inflammatory or nervous disorders,—there is some reason for suspecting that this evacuation is intended, not merely to keep down the quantity of blood in the system, but to secure the evaeuation of something formed in the system during the active state of the genital organs, and which would be hurtful if retained.

The visible change upon the ovaria, which takes place at puberty, consists partly in the formation, or development, in them, of the small bodies called Graafian Vesicles, which contain a serous fluid, and are dispersed through their substance.

The changes which take place in these organs, at the time of sexual intercourse, and particularly the great congestion of blood in them all, must no doubt be ascribed to the influence of sensations and mental feelings ; but the precise extent of the effect of these is uncertain.

Observations on animals, and, in some instances, on the human body, distinctly prove, that at the time of such sexual intercourse as is followed by conception, the fimbriated extremities of the Fallopian tube embrace the ovarium, so as to make a single, though very winding and irregular passage from it to the external parts ; and that thereafter one of the

Graafian vesicles, extending itself to the surface of the ovary, bursts and discharges a smaller vesicle or ovum, which descends along the Fallopian tube, into the uterus; and part of which is there developed to form the embryo. The smaller vesicle seems to have been detected by BAER, even in the ovarium; and to consist of an outer and inner portion, containing a liquid, and the embryo ultimately forms on a part of the sac of the inner portion *. But there is more doubt and difference of opinion as to the following points:

1. Physiologists are not yet fully agreed whether the rupture of a vesicle in the ovary, and escape of an ovum, can take place in the human body, or in others of the mammalia, without impregnation. The numerous observations of HALLER, and of PREVOST and DUMAS, would seem to show that this can seldom happen in the lower animals of this class; but, on the other hand, the observations of VALISNERI, SANTORINI, and BERTRANDI, in Italy †, and of Sir E. HOME and Dr BLUNDELL ‡, in this country, seem sufficient to prove, that, in the human body, and probably in some of the lower animals also, vesicles are occasionally detached from the ovaries, and their marks subsequently found, where there had been no sexual intercourse.

When a vesicle has been ruptured, and ovum de-

* BAER, in BRESCHET's *Repertoire d'Anat. et de Physiol.*, 1829; and ALLEN THOMSON, in *Edin. Phil. Journ.* Oct. 1830.

† See BLUMENBACH, in *Comment. Soc. Reg. Scient. Gotting.* vol. ix.

‡ *Phil. Trans.* 1817, and *Physiological Researches*.

tached from the ovary, it leaves at first a ragged cavity, containing a little blood; but this gradually assumes the appearance of a yellowish substance, called a corpus luteum, with a corresponding cicatrix on the surface of the ovary, which afterwards becomes gradually less distinct. But according to the observations of Sir E. HOME, of MAGENDIE*, and of BAER†, a yellowish substance appears to be formed around one of the Graafian vesicles, before it bursts, and continues, after the escape of its contents, gradually encroaching on, and ultimately obliterating, the cavity left.

It would appear, therefore, that the total absence of any corpus luteum may be regarded as a proof that no conception had taken place, but that the presence of a distinct yellow body in the ovarium, may depend on one of two causes, perhaps independently of conception, certainly independently of the growth of an embryo in the uterus; viz. either on the escape of an ovum, without sexual intercourse, or on the development of a vesicle containing an ovum which has not yet escaped.

2. It is not fully ascertained how far, in the winding canal formed by the adhesion of the fimbriæ to the ovary, it is essential that the male semen should penetrate, and whether its contact with the ovum, or vesicle detached from the ovarium, is necessary in order that it may impregnate the ovum.

That its contact with the ovary itself is not neces-

* *Precis Elementaire.*

† BRESCHET's *Repertoire d'Anat. et Physiol.* 1829.

sary to the discharge of the ovum, appears not merely from the facts already stated, but also from many experiments by Dr HAIGHTON and Dr BLUNDELL, made on rabbits, in which animals there are two uteri corresponding to the two ovaries. In these experiments, different portions of the canals leading from the external parts to the two ovaries, were obliterated by adhesive inflammation, and sexual intercourse afterwards permitted, and the escape of vesicles from the ovaries was clearly ascertained to have followed that intercourse*.

On the other hand, that the seminal fluid must necessarily reach the ovum in the uterus, in order to vivify it, seems to be rendered highly probable, *first*, By the farther result of the experiments of Drs HAIGHTON and BLUNDELL, in all of which it appeared, that, although ova were detached from ovaries, the communication of which with the external parts had been interrupted, yet such ova never were developed into embryos; although those from the opposite ovaria, received into the opposite uteri of the same animals, were so developed; *secondly*, From the observations of GALEN, RUYSCH, CHESELDEN, HALLER, HUNTER, and many others, who found the male semen in the uteri of different animals killed soon after copulation; and especially from the microscopical examinations of PREVOST and DUMAS †, who satisfied themselves of its always existing, in these circumstances, about the horns of the uterus, but

* See BLUNDELL's Physiological Researches.

† Annales des Sciences Naturelles, t. i, ii, iii, & xvi.

could never detect it in the Fallopian tube ; and *lastly*, From the analogy of many animals of the classes of Reptiles and Fishes, in which it is certain that the actual deposition of the male semen on the ova, at the time of, or after their discharge from the body of the female, is the essential condition of their development.

If this be so, the rare cases of extra-uterine conception, where the ovum is developed either in the Fallopian tube, or beyond its extremity, must be cases where a portion of the seminal fluid has penetrated farther than usual along the canal leading to the ovary *. And that this may happen, we can understand from the observation of Dr BLUNDELL and others, that at the time of intercourse, the whole of that canal is in a state of spontaneous movement.

This last fact likewise enables us to understand, consistently with this doctrine, how impregnation should have taken place in several cases on record †, where the vagina was preternaturally narrow, or the hymen nearly entire.

On the other hand, in the case of birds, a single intercourse is known to be sufficient to impregnate many eggs, which are laid successively after it ; and it is

* Cases of extra-uterine conception were published by Mr LANGSTAFF and Dr ELLIOTSON, (*Medico-Chirurgical Trans.*, vol. vii. & xiii.), in which the Fallopian tube was obstructed ; but the facts now stated render it most probable that the obstruction had been subsequent to conception.

† *Ex. gr.* in *Memoires de l'Acad. des Sciences*, 1712 ; *Edin. Med. and Surg. Journ.* vol. i. ; *Medico-Chirurg. Trans.* vol. ii. ; FODERE, *Medecine Legale*, § 252 & 986.

difficult to understand how the semen should have been conveyed to the ovary for that purpose. And we have accounts of experiments, in which artificial impregnation of female animals, by semen taken from male animals, is said to have been effected (by what has been called the Seminal Aura), where the male fluid did not come into actual contact with the uterus of the female*.

3. The time when the ovum leaves the ovarium, and descends along the Fallopian tube, is not certainly known, and probably not uniform; but the observations of PREVOST and DUMAS, MAGENDIE, and others, show that, in various animals, it is not for some days, and that in the human species it may probably be eight or ten days, after the sexual intercourse with which it is connected.

Thus it appears, that the changes in all viviparous animals, at the time of the intercourse which is to be fruitful, are confined to the deposition of the seminal fluid in the uterus, and the adhesion of the fimbriæ to the ovary; and that the growth, detachment, and passage of the ovum or vesicle into the uterus, take place within some days after; during which time, PREVOST and DUMAS found the seminal animalcules to be distinctly visible in the uterus; and it is a probable conjecture, that the implantation of one or more of the animalculæ on the ovum may be the necessary condition to its development.

After such intercourse, the inner membrane of the

* Edin. Med. and Surg. Journ. vol. xix. p. 485.

uterus is found to be lined all over with an effusion of flocculent lymph, part of which stretches across the cervix uteri, and closes its mouth, and the formation of which is not dependent on the passage of the ovum, nor even on the admission of semen into the uterus; for it has been found, both in cases where the conception was extra-uterine, and in experiments where the vagina was obstructed *.

In this flocculent lymph, the ovum, when first seen, is loose and detached; it is much smaller than the vesicle which disappeared from the ovary †; and, according to almost all observers, it appears as a sac containing a limpid fluid, on one side of which the embryo becomes visible, not sooner, according to MARGENDIE, than three weeks after conception.

The sac containing the embryo, when the parts become more distinct, appears to consist of two membranes, the outer of which, called the Chorion, is of loose texture, and its exterior flocculent surface has the name of Spongy or Shaggy Chorion; while the inner, called the Amnion, is smooth and uniform. The lymph lining the uterus, and continuous with the shaggy chorion, also appears separable into two parts, the outer of which is called Decidua Vera, and the inner, supposed to be turned back by the entrance of the ovum, is called Decidua Reflexa. In the course of the second month, the shoots of the shaggy chorion, on one part of the ovum, implant themselves firmly in the corresponding portion of the

* BLUNDELL, loc. cit.

† PREVOST and DUMAS, loc. cit.; and CRUICKSHANKS, Phil. Trans. 1797; BAER, loc. cit.

decidua, generally towards the fundus of the uterus, and form the Placenta, and the rest of the flocculi of the chorion then disappear. The embryo slowly detaches itself from the side of the ovum, and floats in the liquor amnii, the proportion of which to the whole ovum is afterwards gradually diminished; and the only attachment of the embryo to the membranes is then found to be the umbilical cord, by which it is connected with the placenta.

But for a time, before these changes are completed, there is a small sac containing a whitish fluid, called *Vesicula Alba*, between the amnion and chorion, which, according to the observations of BAER, and of ALLEN THOMSON, would seem to be the inner portion of the ovum, above noticed.

The Placenta, formed at first of adventitious membranes thrown out on the inner surface of the uterus, and in which no bloodvessels are discernible, is found, when fully developed, to be a spongy mass composed chiefly of vessels, infinitely subdivided and convoluted. A part of this vascular structure is continuous with, and may be injected from, the arteries of the uterus, and is called the Maternal Portion; but another portion, towards the inner surface of the placenta, can be injected only from the vessels of the umbilical cord of the fœtus, and is called the Fœtal Portion.

How the communication is established between the vessels of the uterine and fœtal portions of the placenta is still somewhat doubtful; the existence of cells in the placenta, into which blood is effused from the uterine arteries, not being clearly demonstrated.

It is probably by transudation only, that the contents of the uterine vessels pass into the minute branches of the umbilical vessels ; and it seems certain that no entire globules of blood are transmitted from the one set of vessels to the other, because the globules of the foetal blood appear from the observations of PREVOST and DUMAS, to be differently shaped from, and larger than, those of the adult.

In experiments by MAGENDIE and by Dr WILLIAMS *, it appeared that camphor, and that oil, injected into the blood of pregnant animals, were soon detected in the blood of the foetus ; but poison injected into the umbilical arteries, although mixing with the blood on its way from the foetus to the placenta, did not affect the mother. Neither does fatal hæmorrhage in the mother apparently diminish the fullness of the vessels of the foetus :—so that it would seem that the transmission of fluids in the placenta is almost entirely from the maternal to the foetal portion.

The placenta must no doubt answer, in some measure, the purpose of arterializing, as well as supplying the blood of the foetus ; but the difference between the blood in the umbilical arteries, coming from the foetus, and that in the umbilical vein passing into it, is never nearly so great as that between venous and arterial blood in the adult ; and to this it is no doubt partly owing, that all the functions of the Nervous System are nearly at a stand in the foetus, but are excited into action immediately after birth.

The gradual formation of the different organs du-

* Edinburgh Medical and Surgical Journal, vol. xxv.

ring the life of the foetus, has been lately much studied both in the lower animals and in the human body, and the growth of various parts minutely described. Some general observations only on this subject can be made here.

1. It is certain that the different parts of the foetus do not result merely from *evolution* of organs already existing in the ovum; but from movement of the fluids, and agglomeration of their particles at particular points, to form different solid textures; under the influence, no doubt, of the same vital properties to which we gave the name of Vital Affinities, on which the nourishment of these textures at all subsequent times depends. Many well-known parts of the different organs, such as the heart and brain, are distinctly seen to be added after other parts have attained a considerable size. It would appear that the ovum, when it first descends into the uterus, has two coverings, the outer of which becomes the chorion, and the inner becomes what has been called the Umbilical Vesicle. This last membrane is first thickened at one part, then separates into distinct layers; these are thrown into folds, which gradually enclose the remains of the vesicle, from which they are at first nourished, and then retain a vascular connexion with the chorion or outer membrane of the ovum, and with the uterus, by the umbilical vessels only; and these folded layers of membrane gradually undergo conversion into the amnion covering, and the different textures composing, the animal body *.

* See the papers of BAER, of ALLEN THOMSON, and of PREVOST and DUMAS.

2. The commencement of the formation of organs in this way is anterior to the first formation of the heart, and to the development of vessels on the umbilical vesicle ; and the part of which the rudiments are first seen is the vertebral column.

3. The growth of the embryo is slow in the earlier months. The form of the trunk is always considerably curved, but the extremities, when first seen, stand out from the body, and are afterwards folded in. The distinction of textures is very gradually effected, so that bone is not distinctly formed before the end of the second month,—muscles and fat not until the end of the third ; and several organs cannot be perceived sooner than the fourth, at which time the weight of the embryo is hardly above two ounces ; after this time it is called the Fœtus. The head of the fœtus, in a great majority of cases, lies ultimately in the lower part of the uterus. The distinction of the grey and white matter of the brain is never distinct in the fœtus ; but the parts of the Nervous System which are first formed are those that consist ultimately of white matter*.

4. After the heart is distinctly formed, and the vessels contain red blood, and when the nourishment is no doubt chiefly drawn from the placenta, it appears beyond doubt that the heart, for a time, consists of one auricle and one ventricle only, from which one artery arises, and that the septum is afterwards gradually formed, the aorta separated from the pulmon-

* See TIEDEMANN'S *Anatomy of the Fœtal Brain*, translated by BENNETT.

ary artery *, and the peculiarities of the foetal circulation established, about the end of the second month.

5. This circulation takes place in the following manner : From the placenta the blood ascends by the single contorted umbilical vein to the umbilicus, and thence by the edge of the broad ligament to the liver, where it joins the left branch of the Vena Portæ, and is distributed for the most part through the left lobe of the liver,—part, however, passing forward by the ductus venosus, directly to the vena cava ascendens, which the rest likewise enters after being distributed through the liver.

When the blood of the vena cava ascendens reaches the heart, the greater part of it is directed at once to the left auricle ; the Eustachian valve, in front of it, preventing much admixture with the blood of the right auricle, at least until the later months, when this valve is shortened. From the left auricle it is projected into the left ventricle, and thence into the aorta ; and nearly the whole contents of the left ventricle appear to pass into the carotid and subclavian arteries, to supply the upper parts of the body, and upper extremities †. Returning from these by the vena cava descendens, the blood passes through the right side of the heart, and is projected by the right ventricle and pulmonary artery, partly into the lungs, but chiefly through the canalis arteriosus into the

* ALLEN THOMSON, loco cit.

† See a translation of KILIAN'S work on the Foetal Circulation, in Archives de Medecine, 1828.

commencement of the descending aorta, which it appears completely to fill, at least during great part of the foetal life. From the internal iliac arteries a great part of this blood ascends by the two umbilical arteries at the sides of the bladder, and passing out by the umbilicus, is carried by the cord to the placenta ;—while the rest is circulated through the lower parts of the foetus, and rejoins it in the vena cava.

The use of the distribution of so much of the blood from the placenta to the liver is still doubtful ; but the other arrangements now described are evidently calculated, not only to expose the blood of the foetus to the salutary changes which it undergoes at the placenta, but likewise to send most of this blood to the upper parts of the body of the foetus, before it visits the lower parts ; to allow a small portion only of this blood to have access to the lungs of the foetus ; and farther, to secure the co-operation of both ventricles of the foetal heart in the circulation through its body.

6. After this circulation is established, it seems to be a general law, that the growth of organs is proportioned to the development of, and flow of blood through, the bloodvessels supplying them. The deficiency of parts of the body in monsters may generally be traced more or less directly to this cause ; and the development of the Nervous System, in particular, appears strictly proportioned to, and dependent on, the development of the vessels supplying it,—the nerves being first formed in most parts of the body, the spinal cord before the brain, and the brain before the cerebellum, and the growth of both these

organs taking place in the direction in which the branches of the carotid and vertebral arteries extend themselves*.

7. There are certain parts fully developed in the fœtus, which shrink and become apparently useless in the adult, and the use of which is still unknown, particularly the Thymus Gland, situated between the layers of the anterior Mediastinum, and the Supra Renal Capsules. The liver and thyroid gland are likewise, for reasons not known, of larger size in proportion to other parts than in the adult; and the urachus connecting the bladder with the umbilicus, has no known use in the human fœtus. Another curious fact is, the development of parts of organs, which afterwards shrink and become rudimentary, even during the fœtal life; of which the most striking is the caudal prolongation of the vertebral column and spinal cord during the first three months; the membrana pupillaris, which lies across the pupil in the earlier months, and the prolongation of the cæcum, which afterwards becomes the Processus Vermiformis, belong to the same class. And a still more curious process is the descent of the testes, from their position on the Psoæ muscles, through the abdominal rings to the scrotum, and the changes, connected with that movement, in the adjoining portions of Peritoneum.

8. The circulation in the fœtus is very rapid, the pulsations of the heart above 120. The secretions, and more particularly the excretions, must necessarily be much restrained during the fœtal life; but a whi-

* See particularly SERRES, *Anat. Comp. du Cerveau*.

tish unctuous substance is formed on the surface in the later months; and there is a copious secretion into the intestines (which are longer in proportion to the size of the body than in the adult), both of mucus and of bile, from which the greenish liquid matter called Meconium is formed, which exists in the lower intestines during the later months, and is discharged soon after birth. In some instances this has taken the exact form of hardened fæces; and from this circumstance, and more especially from the contents of the lower intestines showing little or no albumen, while those of the higher intestines contain albumen in abundance, it appears probable, that there is a process of Digestion of the contents of the intestines during foetal life, on which the nutrition is partly dependent*. The power of generating animal heat is feeble in the foetus, its temperature being 92° or 93°,—which is to be expected from its venous blood being less different from its arterial than in the adult,—from its small supply of oxygen, and deficient secretions. In these circumstances, and in the greater size of the particles of its blood, its vitality approaches to that of cold-blooded animals.

The weight of the lungs of the infant is in general nearly doubled after respiration is established, but the proportion of their weight, either before or after that

* See GEOFFROY DE ST HILAIRE, *Philosophie Anatomique*, p. 288; and more particularly Drs LEE and PROUT, in *Philosophical Transactions*, 1829. Dr LEE having found the albumen also in the hepatic ducts, suspects that the liver is its chief source, and therefore, that the office of the liver is specifically distinct in the foetus and adult.

change, to the whole weight, is exceedingly various ; being, according to the observations of CHAUSSIER, from $\frac{1}{27}$ to $\frac{1}{130}$ in children still born, and from $\frac{1}{10}$ to $\frac{1}{48}$ in those dying very soon after birth. The whole weight, at birth, is, on an average, about 7 lb., and the length about 20 inches.

The changes on the uterus, which attend the development of the ovum within it, likewise demand attention. These are, not only very great enlargement of size, but softening of texture, and alteration of form, which take place gradually, and somewhat variously. For the first three months the uterus remains in the pelvis, and its absolute increase is slow ; but in the next three it increases more rapidly, and rises nearly, or quite, to the umbilicus, and by the end of pregnancy, nearly to the sternum. Its shape is gradually altered, first by the increase of its transverse diameter at its central and lower part, by which it becomes more oval, and afterwards by the expansion of its cervix, which in general takes place almost entirely in the three last months, and furnishes the surest sign of the visible enlargement of the abdomen depending on the development of the uterus.

The constitutional effects which attend pregnancy are, *first*, suppression of the menses, which is nearly invariable ; being in fact the natural result of the formation of the membranes which line the inside of the uterus closely, and cover its mouth, and never separate from it in the healthy state of pregnancy ;—*secondly*, the enlargement of the mammæ during the last half of the time, and more particularly the for-

mation of the brown areola around the nipple;—*thirdly*, various dyspeptic symptoms, particularly the morning sickness;—and *fourthly*, various nervous symptoms, particularly mental languor or irritability. But these, although often very obvious, are not exclusively characteristic; and the dyspeptic and nervous symptoms are in some cases slight, and in many abate considerably after the third month. The movements of the child may be felt occasionally, but of very various strength, during the last four or even five months.

The usual duration of pregnancy is just about 280 days. Many children are born before this time, but very few after it; and the law which allows a child to be legitimate if born six calendar months after the marriage of the mother, or ten months after the death of the reputed father, is generally thought to embrace all possible cases. Yet cases have occurred, in which there was good evidence of children having lived that were born before the sixth month, and of parturition having been delayed beyond the tenth*.

The contraction of the uterus, on which parturition depends, is not the effect of its distention by its contents, but of a change in the vital actions going on in itself; for it is observed, in a certain degree, at the usual time, even in cases of extra-uterine conception. It appears from experiments by MAGENDIE, that there are likewise changes in the placenta, towards the end of pregnancy, tending to the gradual dissolu-

* See, for example, Edinburgh Medical and Surgical Journal, vols. xi. and xxv.

tion of part of the vascular union between it and the placenta, whereby the hæmorrhage attending the ultimate separation is no doubt lessened.

The principal changes during parturition are these,

1. The contractions of the uterus cause pains, recurring at intervals which gradually diminish, for some hours, referred to the back, abdomen, pelvis, and thighs; and, along with these, gradual dilatation of the os uteri.

2. When this is accomplished, the membranes are more or less protruded, and then burst, and the liquor amnii escapes.

3. There is after this an increase and change of the painful contractions of the uterus, aided by sympathetic actions of the diaphragm and abdominal muscles, by which the head of the child (in natural labour), is forced down,—the vagina and external parts being stretched and unfolded to make room for it; and the head changing its direction as it descends, so that the occiput, from being directed towards one of the acetabula, comes to be behind the arch of the pubes, and the face in the hollow of the sacrum. After the head has passed the external parts, the pains become less urgent, and the rest of the body passes more easily.

4. There is subsequently a slighter renewal of the painful contractions, ending in the discharge of the placenta and membranes; then a bloody discharge for some days, with occasional pains, by which coagula are thrown off; a whitish discharge for some time longer; and the uterus gradually returns to its original

form and situation in from twenty to thirty days after delivery.

According to the observations of Dr GRANVILLE, the uterus, at the time of delivery, attains a temperature ten or twelve degrees higher than has been observed in any other part of the body *.

The singular circumstance of the sudden rupture of so many large vessels as those which unite the uterus and placenta, without dangerous hæmorrhage, depends chiefly on the gradual and uninterrupted contraction of the uterus, constringing the mouths of the vessels; and most cases of dangerous hæmorrhage depend on imperfection or interruption of this tonic contraction.

It may be remarked here, generally, that uterine hæmorrhage, leading to separation of the placenta and abortion or premature labour, may very frequently be referred to one or more of the following causes: General weakness, and especially unusual susceptibility of those impressions in the nervous system, which are apt to influence the circulation; general, and more particularly local, plethora; any sudden excitation of the system, whether from physical or mental causes; febrile disease, especially such as proceeds from a contagious poison; local injury, whether from external or internal causes, in the neighbourhood of the uterus. There are also many cases in which abortion depends on original malformation or fatal disease of the fœtus. There are cases which we cannot refer distinctly to any of these causes; and it has

* Phil. Trans. 1825.

been observed, that such cases are remarkably prevalent in certain times or seasons.

The most important change, in the mother, consequent on parturition, is that which takes place in the mammæ, which are already much enlarged, and already, in general, secrete and discharge a small quantity of serous fluid. Within two days after parturition, this fluid assumes the character of milk, which it retains (the proportion of curd however increasing) for many months afterwards. Its discharge is effected, in consequence of the arrangement of the ducts of the gland, by a certain erection of the nipple, as well as by the suction of the child. The flow of blood to the mammæ, during the whole time of nursing, is very much increased, as is obvious from their increased tendency to inflammation. That *sympathetic* change on the secretion of these glands, according to what was formerly stated, is probably dependent, at first, on sensations which result from the action going on at the uterus. Certainly in this, as in other cases to which the term Sympathy is applied, it is by no means a general law, that every change at the uterus is followed by a change on the mammæ. And after parturition, it is certain that the continuance of the secretion depends very much on the emotions excited in the mother by the sight of the infant; and this not only in the human race, but even, according to the observation of HUNTER and of ROULIN, in the lower animals*.

* See Journal of the Royal Institution, No. II., and Annales des Sciences Naturelles, t. xvi. p. 24.

The important changes on the fœtus, consequent on parturition, are all the effects of the interruption of the flow of blood along the umbilical cord; and of the powers of *Sensation*, which are unnecessary for any of the purposes of fœtal life, being excited by the new circumstances in which it is placed. Its first respiration may be ascribed, partly to the cessation of the small supply of imperfectly arterialized blood, which its lungs had received from the placenta, but chiefly to the novel impression of cold air on the surface of the body. The changes in the circulation within the chest, the gradual closure of the foramen ovale, and the more rapid obliteration of the canalis arteriosus, for which provision had already been made in the altering form of the parts, are to be ascribed chiefly to the expansion of the lungs, and the vital and chemical actions established there, which *solicit* the flow of blood into the lungs, and therefore fill the left side of the heart from them. The changes in the lungs themselves, their great increase of absolute weight, and great diminution of specific gravity, which are likewise effected gradually, are the natural result of the admission of much additional blood into their vessels, and of air into their cells. The continuance of the acts of respiration, the instinctive movements of the limbs, eyes, &c. and the instinctive acts of sucking and deglutition,—being all the natural effects of sensation in the living body, and especially of the establishment of the feeling of anxiety from want of air, and of the appetites of hunger and thirst,—are all to be ascribed to the increased Sensibility,

which results from the action of perfectly arterialized blood in the nervous system. Thus it is that Life, which, during the foetal state, is Organic only (and may therefore be maintained without brain or spinal cord), now becomes truly Animal, and is placed in dependence on Sensation.

Another subject of importance in this department of physiology is the influence of the constitution and habits of parents on their offspring.

That the stature, complexion, forms of features and limbs, &c., as well as the mental peculiarities of the offspring, frequently bear a strong resemblance to those of the parents, is matter of familiar observation ; —it is certain also, that resemblances in these respects are observed nearly indiscriminately to both parents ; —and it has often been noticed, that such peculiarities have passed over one generation, and appeared in the next. Peculiarities of formation, such as supernumerary fingers or toes, have in like manner often been hereditary in families, sometimes descending by the females and sometimes by the males, and yet been found only in a certain number of the members of these families *. In like manner longevity is very often observed to be hereditary † ; and it is therefore quite in conformity with other ascertained facts, that we find the tendency to certain diseases, particularly to Asthma, Gout, Mania, and the various forms of

* See CARLYLE in *Philosophical Transactions*, 1814 ; and HALLER, *Elem. Physiol.* tom viii. p. 96.

† See a collection of cases of this kind in Sir J. SINCLAIR'S *Code of Health and Longevity*, vol. i. p. 27.

disease which are ranked together under the term Scrofula, to be much greater in some families than in others; although in many cases it is only by the action of well-marked exciting causes, that such diseases, even in persons so predisposed to them by hereditary constitution, are produced.

Various observations appear to indicate, that the sex of the offspring is in some measure dependent on the relative energy of the parents; being most frequently male, when the male parent has been of the stronger habit of body, and *vice versa* *. Whatever be the causes acting on parents, which influence the sex of their offspring, these causes must operate on the whole, very uniformly over the world, and so as to cause a slight preponderance of the number of males, the male births exceeding the female very generally in all countries, and nearly in the proportion of 21 to 20.

The age of parents must also, no doubt, influence the constitution of their offspring;—those who are in the vigour of life being best fitted for the procreation of children of strong constitution; but statistical statements from different countries show, that the average productiveness of marriages is very different in different stages of advancement and civilization—no doubt because marriages are usually contracted much later in some of these countries than in others,—without any corresponding difference in the average health of the community; from which it may be in-

* See GIROU DE BUZAREINGUES in Ann. des Sciences Naturelles, tom. xv.

ferred, with more confidence than from any individual observations, that both men and women are equally capable of the procreation of healthy offspring during a considerable part of their lives.

We have no means of judging in what manner peculiarities, either of the male or female parents, are impressed on their offspring; but it is an important fact, that the influence of the male, in the case of some animals, is not confined to the ovum which he actually impregnates; the peculiarities of a male animal, that has once had intercourse with a female, having been distinctly recognised in the offspring of subsequent connexions of that female with other males*.

The acquired habits, and mode of life of parents, have likewise a very important influence, which is well ascertained on a large scale, but cannot be easily demonstrated by individual instances, on the character of the vital actions, which their offspring will exhibit. In so far as the mode of life of parents is permanently debilitating, and disposes them to scrofulous disease, it is certain that it will generally give a similar tendency to their progeny; as is evident on comparing the amount of scrofulous disease in the young children of a great town, with its amount in the previous generations of the same families, if engaged in agricultural employments. The effect of habits of parents on the vital actions of their offspring is well illustrated by the great variety of appearances assumed

* As in the instance of an Arabian mare that had been once covered by a quagga. Philosophical Transactions, 1821.

by animals when domesticated, and their return, in the course of a few generations, in a state of nature, to a single and uniform type*.

But a more singular fact, which appears well ascertained in regard to certain animals (dogs and horses), and probable in regard to the human species also, is the transmission, to the second and third generation, of habits not natural to the animal, but acquired by education and training†.

Again, it is certain that various accidental circumstances affecting the mother during gestation, may influence the nutrition and subsequent vital actions of her offspring. It appears, from the observations of GEOFFROY ST HILAIRE‡, that preternatural adhesions of parts of the fœtus to the membranes and the placenta occur occasionally, and so confine and derange the circulation in, and development of, the fœtus, as to produce various kinds of monstrosities; and both from his observations and those of many others, it seems well ascertained, that such derangements of the vital actions within the uterus, may be produced either by injuries, or by sudden and violent mental emotions, when these are not so powerful as to cause abortion. If the observation of Sir E. HOME§ shall be confirmed, that nerves may be dis-

* See ISIDORE ST HILAIRE, "Considerations sur les Mammifères;" and "Recherches sur quelques changemens observés dans les Animaux Domestiques," &c., by ROULIN, in *Ann. des Sciences Naturelles*, t. xvi.

† See ROULIN's paper, above quoted; and the report on it, by GEOFFROY ST HILAIRE.

‡ *Philosophie Anatomique*, pp. 208 & 527.

§ *Philosophical Transactions*, 1825.

tinguished in the placenta and umbilical cord, the efficacy of mental emotions, on the growth of the foetus, may be more easily understood. It is much more doubtful, whether the precise nature of the alteration effected in any case on the growth of the foetus, can be determined, as is vulgarly supposed, by the images in the mind of the mother; but as we know, from such facts as that noticed above (p. 401, *note*), that the peculiarities of a male animal may influence the products of conceptions in which he is not himself concerned, we are hardly entitled to deny the possibility of such an agency of mental affections.

SECTION XVIII.

OF PECULIARITIES OF AGE, SEX, AND TEMPERA-
MENT.

THE vital actions of all warm-blooded animals, immediately after birth, approach in several respects to those of cold-blooded animals. Their circulation, although very rapid, is easily repressed, particularly by cold *; their power of generating heat is feeble, and in the human species, and many others, would be insufficient, of itself, to preserve life; their sensibility, and mental powers, are imperfectly established; and their lives are chiefly spent in sleep;—but on the other hand, they have more endurance of life, in different circumstances; the same degree of reduction of their own temperature †, the same length of suspension of the function of respiration ‡, and the same amount of destruction to the Nervous System §,—is not fatal to the vitality of their organs of circulation, as in adult animals.

The following appear to be the most important peculiarities which appertain to the periods of childhood

* See EDWARDS, *De l'Influence des Agens Physiques*, &c. Part III. ch. i.

† Ibid. Part IV. ch. ii.

‡ Ibid. Part III. ch. iv. and Part IV. ch. vi.

§ LEGALLOIS.

and early youth, gradually diminishing as life advances,

1. The capillary vessels, and particularly the capillary arteries, are much more numerous in all the textures, and bear a much greater proportion to the larger vessels, as is obvious on comparing the red lines in an aged countenance, with the diffused bloom of youth, and as is more distinctly shown, by injections of subjects at different ages ; so that the blood must diverge much more into the interior of the textures, than in adults.

2. During the whole period of youth, the irritability of the organs of circulation is evidently greater than in adults ; the number of pulsations of the heart, at first double that in the adults, is only gradually reduced, and is easily raised by various kinds of excitement ; hence a febrile state, with increased heat of skin, is much more easily produced than in advanced life, and if excited by inflammation, is of greater intensity, and of greater duration, than that which the same extent of inflammation, in advanced life, would occasion.

3. The vital action of the vascular system, although more easily excited and increased, has not (according to the general observation of physicians) so much strength or endurance, as in adults. It is more easily depressed, not only by cold, as already stated, but by evacuations, particularly of blood.

4. The organic functions going on in the capillary vessels take place with greater rapidity ; as appears, not only from the growth of the body, but from di-

gestion being more rapid, and more frequent reception of food being required ; from the bowels being more open ; and again, from the body wasting more rapidly under the influence of any disease which impairs digestion.

5. The peculiarities of the functions of the Nervous System during youth are analogous to those of the organs of circulation. The Nervous System appears more susceptible of change of all sorts, or to possess more *mobility*, than in more advanced life. All objects of sensation impress themselves more strongly on the attention, and thereby on the recollection, and knowledge of all sorts is more easily acquired. All the natural desires are more lively, and the flow of thought more rapid ; but the power of continued voluntary attention, either to objects of sense, or to mental abstractions, is less. Muscular motion is more grateful ; continued inactivity is felt as a greater restraint ; and variations of any combined voluntary movements are more easily performed, so that the physical education is easier ; but the strength and endurance of the power of voluntary muscular contraction are inferior to what they afterwards become. Mental emotions are more easily excited, and their influence on the body is more obvious ; but they are also more transient and capricious.

The body does not attain its full height till some years after the time of puberty ; the growth in other directions continues, although slowly, for a time after the full height is attained ; and it is not until the

growth in all directions is completed, that the bodily strength is greatest.

The brain is probably the first part of the body which attains its full size, being, in general, as large about seven years of age, as subsequently. The growth at the extremities of the body appears manifestly to be accelerated by a sedentary life (when the health continues good) and to be somewhat retarded by habits of muscular exertion, which solicit the flow of blood into muscular parts. The growth is, no doubt, accelerated and invigorated by frequent alternations of temperature within certain limits; but is permanently checked by habitual exposure to extreme cold, as in the Arctic Regions.

Growth, in all parts of the body, after birth, appears to take place, not as in the earlier periods of foetal life, by deposition from the fluids, to form new organs, but by the extension of parts previously organized. And the vessels of every organized texture possess the power (although in very various degrees), of throwing out, under certain circumstances of injury or disease, lymph which shall gradually assume the properties of that texture. But the deposition of bone, whether between membranes, as in the cranium, or in cartilages, as in the extremities, takes place in parts already formed; it is always preceded by increased vascularity; and the deposition of the new bone appears to be chiefly at the extremities of the bony fibres already formed. The cartilaginous rings which unite the epiphyses with the shafts of the long bones, and the sutures of the bones of the head, allow of growth

of bones taking place in this way, without any extension of fibres already formed ; and some experiments of Mr HUNTER* have been thought to indicate that bones never do grow in this last way. But the changes which take place in the lower jaw, long after birth, are enough to show, that bony fibres may grow by extension of their parts, as well as by deposition at their extremities.

Most of the second set of teeth are formed within, as well as protruded from, the maxillary bones, at different periods after birth.

The changes which take place on the body in old age (but which begin at very different periods of life in different persons), cause peculiarities nearly the reverse of what were remarked in youth. The circulation in the capillary arteries becomes gradually more confined to the larger of those that communicate with veins, while many of the smaller are obliterated ; and the power of generating heat is again diminished. The circulation is somewhat retarded, and gradually enfeebled, notwithstanding that the pulse often feels strong, by reason of the diminished elasticity and vital power of the arteries. The same amount of inflammation, or of other diseased state of the body, excites less febrile reaction than formerly ; and any diseased action established in the vascular system, shows less tendency to spontaneous abatement. The cells of the lungs are remarkably enlarged, so that the action of the blood and the air in

* See Transactions of a Society for the Improvement of Medical and Surgical Knowledge, vol. ii.

the lungs must be diminished. Nutrition of all the textures takes place more slowly; the *decrementum corporis* is established; the textures become generally more rigid; the proportion of fluids is diminished; the cornea is flattened; many of the cartilages, and sometimes certain of the membranes (independently of any decided disease), become bony. The senses become somewhat blunted; muscular exertion, and especially any new combination of muscular actions, becomes irksome; as the vital power of the muscles diminishes, the desires become less keen; the disposition to fix the mind on any new object of thought is lessened; and the associations connected with these become few and feeble; so that the recollection of them is soon lost. Mental emotions are less easily excited, and their influence on the body is less obvious. But in different individual cases, there is very great variety in these respects.

The peculiarities of the female constitution, in the functions common to both sexes, are seen chiefly between the time of puberty and the cessation of the menses. The branches of the descending aorta, supplying the abdomen and pelvis, are not only larger, but are more habitually liable to variation in the quantity of their contents; and hence probably it happens that inflammations, and other diseases of the parts supplied by these vessels, are more easily induced. The nourishment of the organs concerned in locomotion is less active, and that of the cellular and adipose textures generally more active than in man. But the chief difference is in the functions of the

nervous system. The sensations in women are probably more acute, or their minute differences more easily discerned; the mind is more easily impressed by any new object of thought; the disposition to active and sustained exertion, whether mental or bodily, is less, and the mental Emotions are stronger, and arrest the attention more forcibly, than in man; so that women are more habitually under their influence. They are less guided in their conduct, by simply intellectual acts, directed to the attainment of definite objects, and are more apt to be biassed in their judgments, by preconceived feelings; but these feelings are very generally disinterested, and true to the purposes for which they are destined by nature. The great influence in all the functions of women, of sensations and emotions, and of changes in the nervous system, which affect the other organs nearly in like manner as these mental feelings do, is very important in reference to many of their diseases.

The influence of habits and external circumstances on the human constitution is obviously great, but not easily referable to distinct principles. It is illustrated by the difference between the vigorous circulation, muscular strength, strong mental determination, but deficient sensibility, or versatility of mind, which often characterise men habituated to the labours of the country; and the feebler circulation, inferior muscular power, and less tenacity of purpose, but the greater acuteness of sensibility, and greater activity of mind, generally observed in the inhabitants of great towns; and such differences modify very materially both the

kinds of disease to which these persons are liable, and the action of remedies upon them. A difference in some respects similar is seen on comparing the usual temperaments of the inhabitants of the North and South of Europe.

An enumeration of the peculiarities of the different races of mankind would require a long discussion; and ample information may be found in the works of LAWRENCE, PRICHARD, MAYO, DESMOULINS, EDWARDS, &c. In Europe, it would appear that two races, in some respects considerably different, have existed almost from the earliest periods of history,—the one characterized by black hair and eyes, and a dark complexion; and the other by light coloured or red hair, generally blue eyes, and a fair or florid complexion. Individuals of the first race belong generally to the nations originally Celtic; they constitute the bulk of the population of France, Italy, and Spain, and have been divided by medical authors into those of the choleric and those of the melancholic temperaments. Those of the second race are generally of Gothic origin; they predominate greatly in Germany, Denmark, and Sweden, and have been divided into those of the sanguine and those of the phlegmatic temperament*. In the British Islands, and in Switzerland, there appears to be a greater mixture of these races than in most other countries.

The differences between the great divisions of black and white men, and some of the subordinate divisions

* See GREGORY'S *Conspectus*, cap. xxiii.

of nations, in different quarters of the globe, are much more striking. The secretion on the cutis vera, which gives the black colour to the skin, appears to assist in fitting men for residence in hot climates; because, although such skin, by absorbing more caloric, rises to a higher temperature under the sun's rays, than white skin does, yet it does not inflame from that temperature*; and as the radiation of caloric from it, when its temperature is higher than that of surrounding objects, is greater than that from white skin, those who have it must enjoy greater alternations of temperature.

But it appears evidently from what has been observed of the comparative liability of whites and blacks to different diseases, (especially of remittent fever, inflammations of different parts, and the Indian cholera), and of the difference of the course of these diseases in them, that the various races of blacks and whites differ from one another in circumstances not to be explained by the colour or texture of their skin, and which have not yet been satisfactorily investigated.

The study of such varieties, consistently with health, in the human species, forms the proper connecting link between the subjects of Physiology and Pathology.

* Sir E. HOME, in Phil. Trans. 1821.

APPENDIX.



APPENDIX.

HEADS OF LECTURES ON PATHOLOGY AND THERAPEUTICS.

PART. I. PATHOLOGY.

THIS subject has been generally treated along with the Physiology; but it is impossible to give a satisfactory account of the changes that take place in any disease, or even in consequence of an injury, without reference to the Physiology of different parts of the System; and therefore all such discussions are better postponed, until the healthy condition of all the functions has been examined.

PRELIMINARY OBSERVATIONS.

The alterations of structure of the various organs, or Organic Lesions, produced by diseases, present more definite objects of study, both during Life and after Death, than most other morbid phenomena. But there are frequent and fatal diseases, which do not necessarily leave any such marks behind them; where such lesions exist, they are plainly the effects of previous diseased conditions; and when once formed, they very seldom admit of much alteration from the use of remedies. Hence the study of these changes, although an essential, can form but a small part of a rational and useful System of Pathology.

Such a System must be mainly founded on certain *ultimate facts*, in regard to the operation of external causes on the living body, and the modes of diseased action assumed by its different parts, which are known to us by observation only, and could not have been inferred from our knowledge of the structure and healthy action of parts.

Some of these first principles of Pathology are more distinctly exemplified in cases of sudden death, and in the effects of violent injuries, than in cases of disease; and therefore we premise an account of different fatal injuries, to discussions on the Pathology of any Diseases.

The action of all causes of violent or sudden death may be referred to two modes of injury, which are perfectly distinct in some instances, although in others they appear to be blended. 1. Destroying directly the vital action of the Heart and other Organs of Circulation. 2. Obstructing the Arterialization of the Blood, and so arresting the Circulation in the Lungs.

The first effect may be produced chiefly in two ways. 1. By Concussion or Shock, destroying the vital power in the Sanguiferous System. 2. By Abstraction, sudden or gradual, of the Vital Stimulus. The second effect is also produced in two ways: 1. By injury of the Nervous System, arresting Respiration through the intervention of Insensibility or *Coma*; 2. By direct impediment to the access of Air to the Blood, producing *Asphyxia*.

To these principles we can ascribe,

1. The effect of various injuries, affecting the functions or the structure of the Nervous System.
2. The effect of violent and overpowering Emotions or Sensations.
3. The effect of Excessive Cold.
4. The effect of Excessive Heat.
5. The effect of Lightning.

6. The effect of different Poisons.
7. The effect of Hæmorrhage.
8. The effect of Fasting.
9. The effect of all means of obstructing the access of Air to the Lungs.

The fatal tendency, in different diseases, and even in different cases or periods of the same, is very different, and often complex; but is always susceptible of illustration from reference to these cases of violent death.

We arrange the subject of Pathology as nearly as possible in the same order as the Physiology.

I. The *first* Head of the Diseased Actions that we examine, consists of those in which the Organs of Circulation are chiefly concerned. We do not affirm, that the affection of the Circulation is the primary change in these diseased actions, but it is the most obvious, and that by which the application of remedies is chiefly guided. Of these, a few appear to consist essentially in alterations of the Heart's Action; the greater number manifestly originate in the Capillary Vessels.

OF DISORDERED ACTION OF THE HEART.

1. Syncope.—Its Symptoms and Varieties—Its Causes; both those which act primarily on the Nervous System, and those which act by diminishing the quantity or altering the distribution of the Blood. The Ratio Symptomatum. Cases in which Syncope is itself dangerous. Importance of this affection in relation to other Diseases.

Question, Whether even the causes which alter the quantity or distribution of the blood, do not act on the Heart chiefly through the intervention of Nerves?

2. Palpitation and irregular action of the Heart (independently of any mechanical obstruction to the Course of the Blood)—their Symptoms—Causes, predisponent and exciting—and the Ratio Symptomatum.

OF INFLAMMATION.

I. Phenomena or Symptoms of Inflammation.

1. The Local Symptoms resulting from the Inflammatory Action itself.

2. The General or Constitutional Effects resulting from it. Their varieties in different inflammatory diseases, different habits of body, and different circumstances of patients.

3. General View of the Symptoms, local and general, which may result from the altered functions of different inflamed parts, and which indicate the Seat of the inflammation.

4. General observations on the circumstances in which inflammations are *latent*.

II. Local Effects and Terminations of Inflammation.

1. Congestion of Blood in the minute vessels—Effusion of Serum—Effusion of Lymph, and its effects, whether beneficial or injurious—Softening of Textures from Inflammation—Hardening of Textures from Inflammation—Suppuration—Ulceration and its varieties—Gangrene; the Textures in which these chiefly occur; and the symptoms, local and general, which result from, or accompany them.

2. Spontaneous termination of inflammation by Reso-

lution, with or without any of the other results now mentioned; abatement of the Symptomatic Fever, consequent on, but not always simultaneous with, this change.

III. Remote or External Causes of Inflammation.

1. The Exciting.—Mechanical and Chemical Irritation—Heat—Cold—Poisons—Contagions.

2. The Predisponent.—Heat—Cold—Various causes of Debility—Determinations or Congestions of Blood—Previous Inflammation.

IV. Proximate Cause of Inflammation, or Explanation of its Phenomena.

These phenomena bear so little analogy to any other facts in nature, that we cannot expect to go far in the explanation of them.

The agency of Injury in exciting local Inflammation, is so far illustrated by the observed effect of a stimulus applied to a small Artery; and the agency of other causes is to a certain degree analogous to those phenomena in the healthy body which are called Sympathetic.

Question, How far the intervention of Nerves is essential to the excitation of inflammation?

Question, What is the essential nature of the changes effected in the vital actions in the small capillaries?

The most leading facts as to the state of the vital actions are, 1. The increased propulsion in the arteries leading to an inflamed part. 2. The increased quantity of blood delivered into the veins of an inflamed part, in the earlier stages. 3. The constriction of the capillary arteries, and increased velocity of blood generally seen at first, on microscopical examination of minute inflamed parts, but quickly succeeded by their distention, and by slow motion of their contents. 4. Effusions into the

neighbouring textures, and alterations of these, coinciding with this stagnation in the capillaries.

Most of the facts relating to inflammation, its causes and consequences, indicate an *increase* of vital action in the vessels first and chiefly concerned; while others, particularly the distended state of these vessels, and slow motion of blood within them, seem rather to denote a *diminution* of their action on their contents.

Probably neither term exactly denotes the alteration of vital action that occurs in the Capillaries in the inflamed state; but there are facts known in regard to the structure and healthy action of Arteries, which go far to reconcile the appearance of stagnation in the vessels of an inflamed part, with the notion of the action of these vessels being increased, at least in the commencement of the affection.

As, however, it is very doubtful whether the action of vessels is the sole cause of the motion of blood in the Capillaries, so it is equally doubtful whether any alteration in their action is the sole cause of the different phenomena that occur in inflamed parts; and it is certain that the changes wrought on the blood in inflammation, cannot be explained merely by alteration of the force compressing and propelling it.

The first stage of the Constitutional Fever excited by Local Inflammation, bears a certain analogy to the phenomena called Sympathetic, and to the effects, on the general System, of the injuries already considered; and many of the subsequent febrile symptoms are explained in the way first suggested by HOFFMANN, and illustrated by CULLEN, by a deficiency of vital action in the Capillaries over the system, perhaps dependent on a permanently constricted state of the capillaries.

The effusions of Lymph and of Serum from Inflammation, and their effects, are natural consequences of an increased

action of vessels, and of the properties of the blood; but the circumstances on which the formation or secretion of Pus essentially depends, are very imperfectly understood. It would appear from recent observations, that it may be formed *within* the vessels of an inflamed part, and is not always necessarily thrown out of the vessels.

Question, Whether the Heetic Fever of Suppuration depends on Pus circulating with the blood?

The dependence of Ulceration on increased absorption from parts in a certain stage of inflammation, has been clearly illustrated by Mr HUNTER, but the causes of this increase are often obscure.

The occurrence of Gangrene from Inflammation is, to a certain degree, illustrated by the general law of diminution of vital power from over excitement; but the occurrence of this effect is almost always determined by the influence of some other cause acting simultaneously with the Inflammation, and depressing the vital power; sometimes by an internal cause, such as a diseased state of the arteries, Palsy, Dropsy, &c.; sometimes by an external cause, such as a previous violent concussion, or the action of a contagious poison.

V. Modes of fatal termination of Inflammatory diseases, illustrated by reference to the simpler cases of violent death already considered.

Inflammation is fatal, either

1. By a rapid depression of the vital powers of the Circulating System, analogous to concussion, and independent of any change of texture in the inflamed part,—chiefly seen when the part affected is in the Abdomen.

2. By fluid Effusions on the Brain, or the Lungs, or Air-passages, causing Coma or Asphyxia.

3. By Effusion of Lymph, causing similar changes.

4. By some of its products, taken into the blood, acting as a poison.

5. By gradual Exhaustion of the vital powers during Suppuration or Gangrene.

6. By passing into, or blending itself with, other kinds of diseased action to be afterwards mentioned.

VI. Varieties of Inflammation.

1. Varieties dependent on the texture affected.—Comparison of the course and effects of Inflammation in different Textures.

2. Distinctions of acute, subacute, and chronic Inflammation.—Causes and effects of these varieties.

3. Distinctions of Circumscribed or Phlegmonous, and Diffused or Erythematic Inflammations in external parts; *first*, as to the nature of the inflammation; *secondly*, as to the nature of the fever, and its proportion to the extent of the inflammation. Inquiry whether similar differences exist in internal inflammations.

4. Distinctions of Healthy and Scrofulous Inflammation, as to their appearance, usual duration, and consequences.

Healthy Inflammation may not only take place in Scrofulous habits, but may coexist with Scrofulous Disease; and Scrofulous Action may, in certain circumstances, be excited in a constitution previously healthy. Nevertheless, it is important to observe, and have a name for, the peculiarity of habit, as well as the external circumstances, in which Scrofulous Action is by far the most frequent and most dangerous.

Description of the Scrofulous Habit.

Its External Causes—Hereditary Descent—Climate—Diet—Habits of Life—Other Debilitating Causes—Probable mode and extent of the influence of each.

Question, How far various morbid deposits, and altera-

tions of structure, to be mentioned afterwards, and which occur chiefly in serofulous habits, can be regarded as effects of Serofulous Inflammation?

5. Distinctions of Simple Inflammation, both as to Symptoms and Effects, from other varieties which appear to be *specific*.

Rheumatic Inflammation.

Gouty Inflammation.

Syphilitic Inflammation.

Different species of Inflammation of the Skin and of the Fauces.

OF LOCAL DETERMINATIONS OR CONGESTIONS OF BLOOD.

Habit of Body in which these are most apt to occur, (independently of organic disease),—Circumstances which favour them,—Various symptoms and effects which they may produce in different parts of the body.

Difference between the contents of the Cranium and other parts of the body, in regard to such derangements of the Circulation.

Hæmorrhages, and other kinds of diseased action to which they predispose at different periods of life, and in different habits of body. Organic Lesions directly resulting from them, particularly in the Lungs and Brain, and their effects.

OF IDIOPATHIC FEVER.

I. Its Symptoms, and the changes they denote.

1. Those of a single febrile paroxysm, and its spontaneous solution.

2. Those of the different forms or types of Fever.

3. The Varieties dependent on Concomitant Local Inflammations, or Congestions approaching to inflammation, *first*, at the commencement of the disease; *secondly*, during its continuance (when the parts chiefly affected are the Brain, the Mucous Membranes, and sometimes the Lungs or Liver); *thirdly*, in its decline, where very various parts may become inflamed.

4. The various appearances found on Dissection after Fatal Fevers; description of those which are strictly morbid, in the head, chest, and abdomen;—limitation of the inferences as to the nature of the disease, which they suggest.

II. The Remote or External Causes of Fever.

Malaria probably the sole Exciting Cause of Intermittent or Remittent Fever,—the proofs of its agency,—the circumstances of its production.—and facts known in regard to its operation.

Circumstances in which a truly Continued Fever appears to originate from a Malaria.

Contagion the chief Exciting Cause of the Common Continued Fever. The evidence by which this is known consists simply of the accumulation of facts, which prove that those who have close intercourse with persons ill of it, are themselves affected (*cæteris paribus*) in a proportion very much greater than those who avoid such intercourse. Circumstances in which the contagious property of the disease is chiefly observed, and facts ascertained in regard to its operation. Period during which the Cause of Fever (whether Intermittent or Continued), lies latent in the System; and Causes, which, if applied during this period, appear often to excite the disease.

Debilitating causes which predispose the body to suffer from Malaria or Contagion.

Question, Whether the most powerful of these predisposing causes, imperfect nourishment, and mental depression, are of themselves adequate to the production of Fever, which may afterwards spread by Contagion; or in what other circumstances this spontaneous origin of Fever may happen.

III. The Proximate Cause, or Explanation of the Phenomena of Fever.

Limitations imposed by the nature of the subject, on the results of this inquiry.

Attempt made by different authors to refer all Febrile Action to Local Inflammations, and thereby to resolve Idiopathic into Symptomatic Fevers. This theory is neither consistent with facts, nor adequate to the explanation of the phenomena.

Reasons for thinking that the External Causes of Fever act primarily on the Nervous System.

Question, Whether they act on it directly, or by first effecting changes in the Blood?

Analogy of the changes that constitute Fever to the Effects of Concussion,—to the Effects of certain Poisons,—and to the case of Symptomatic Fever already considered. Its distinctions from all these. The peculiar *depression* of Idiopathic Fever is referable only to the peculiar agency of its Causes, partly on the Nervous and partly on the Vascular System; but many of its Symptoms are explained in the same way as those of Symptomatic Fever.

Question, still undecided, Whether Critical Evacuations are the cause or the sign of the solution of Fever?

Question, In what manner the different Local Inflammations, and Congestions of Blood, often co-existing with Fever, are connected with it?

The Symptoms and Effects produced by each, whether in the Organs furnishing the Secretions, those connected with them in function, or those more distantly connected with them.

Their remote Causes—Habits of Life—Intemperance of different kinds—Mental anxiety or depression—Heat and Cold—Injuries—Previous disease.

Their usual consequences and terminations.

The influence they exercise on diseased actions in other parts of the system.

Question, Whether Diabetes is to be considered as essentially a disease of Secretion, of Assimilation, or of generally increased Absorption?

OF DISEASED STATES OF THE FUNCTION OF NUTRITION.

These changes are of two kinds. 1. Morbid Growths. 2. Morbid Changes of Texture, without increase of substance.

These Organic Diseases become obvious to the senses only when already somewhat advanced; but their existence is often indicated earlier, partly by symptoms depending on the diseased conditions and diseased actions which produce them, and partly by symptoms depending on the altered functions of the parts in which they form, or with which they are connected.

Taking the Effusion of Coagulable Lymph, such as results from injury or inflammation, as the simplest kind, and often the basis of morbid growths, the most important degenerations from this may be enumerated as follows:

I. Those which are generally Local.

1. Sarcomatous Tumours; 2. Encysted Tumours; 3. Osseous Tumours; 4. Scirrhus Tumours.

II. Those which are generally Constitutional.

1. Tubercles,—both the Scrofulous and those unconnected with distinctly Scrofulous Disease.

2. Enecephaloid Tumours, or Fungus Hæmatodes.

3. Melanosis.

Usual progress of each of these kinds of Organic Disease,—Symptoms which usually attend the formation of some of them, wherever situated,—Frequent Combination of several of them in the same individual, or even in the same Tumour.

Question, how far they are liable to Absorption, and return to the natural state.

Examples of morbid changes of texture of solid parts taking place, without either previous increase of substance or ulceration.

Examples of Ulceration, without either distinct previous inflammation, or morbid growths.

Predisponent and Exciting Causes of these Formations, in the same order as stated in regard to the Secretions;—their explanation similarly limited.

Question, how far they are dependent on increase of vascular action in their neighbourhood;—Essential difference, in this respect, between the simple effect of Inflammation, and a morbid growth that has become organized.

Having illustrated these varieties of organic disease, we go on to take a general view of the kinds of these changes usually observed, the Symptoms they excite—their Causes—their Progress—and Consequences,—in each of the following situations :

1. In the Organs of Circulation.

2. In those subservient to Respiration.

3. In those subservient to Digestion and Excretion.

4. In the Nervous System, and Organs of Sense.
5. In the Bones, and other Organs of Locomotion.
6. In the Organs of Generation.

OF DISEASED EXHALATIONS.

Symptoms of Dropsical Effusions in different parts of the System;—they are the accompaniments and consequences of other Diseased States, hardly ever the sole Diseases themselves.

External Causes of these;—in a general view, those which excite Inflammation, and those which excite Organic Disease.

Internal Causes, and Explanation of these,—their connexion with Inflammation of different parts; with previous Exanthemata; with Organic Disease of the Heart, Lungs, Liver, Kidneys, &c.; with Debility.

The different modes in which Diseases, attended with Dropsical Effusions, prove fatal.

The *third* class of Diseased Actions to be considered, consists of those which appear to depend essentially on changes of the Fluids.

Scorbutus.

Diseases observed from damaged or diseased grain.

Diseases observed from other ingesta acting slowly as poisons.

Their Symptoms,—their remote causes,—the variety in the action of these. These diseases are apparently often dependent, not simply on the nature of the ingesta, but partly also on the state of the vital powers.

Purpura or Hæmorrhœa petechialis. Its symptoms and complications with other diseases. Its causes quite unknown.

Question, Whether the *Specific* Inflammations, the *Contagious* Febrile Diseases, and the *Constitutional* Organic Diseases, depend, in part, on altered conditions of the Fluids? and if so, Whether such alterations result directly from external causes, or are the effect of diseased actions of the Solids? No satisfactory information on this subject to be expected, till the nature and limits of the property, above called Vital Affinity, shall have been better ascertained.

The *last* head of Diseased Actions to be considered, consists of those in which the functions of the Nervous System are chiefly concerned.

Many derangements of the functions of the Nervous System are the effects of other kinds of diseased action, already considered; but some cannot be traced to any such source. Even when themselves dependent on previous diseased states, they often react on the functions of other parts, and aggravate or extend the original disorder.

In treating of each of the different derangements of these functions, therefore, we first shortly consider how far it may be the effect of injury,—of disorder of the circulation,—of diseased secretions, and their attendant changes,—or of alteration of texture of the Nervous System itself, or neighbouring parts. Afterwards we examine the cases in which derangement of these functions appears to be the primary disease. As the actions of the Nervous System, in the healthy state, are known only by their effects, we cannot possess any intimate knowledge of their

diseased conditions; but we can state the characteristic symptoms of these—their remote causes, so far as they are known—and their usual progress and consequences.

In this way we treat,

1. Of the state of Coma.
2. Of Affections of those Muscles which are habitually moved by the Nerves: Palsy,—Spasm, 1st, Of the simply voluntary Muscles, and 2dly, Of some of the Muscles concerned in Respiration.
3. Of affections of the External Senses, including Anæsthesia, and Neuralgia or Nervous Pain.
4. Of affections of the Mental Faculties: Amentia, and General and Partial Insanity.—The laws by which the succession of thoughts is regulated, are the part of the mental constitution which undergoes the chief alteration in disease. Causes, bodily and mental, which produce such alteration,—its Varieties,—Connexions of mental with other diseases.

PART II. THERAPEUTICS.

As there are first principles in Pathology which could not have been deduced from the Physiology, so there are first principles in Therapeutics, or general facts ascertained in regard to the effect of remedial agents, which are known to us by observation only, and could not have been anticipated *a priori*. Nevertheless, the effect of many remedies is to a certain degree explained by reference to principles already stated.

Short illustration of the fallacies to which a merely empirical observation of the effects of remedies is liable; from the variety of individual cases of disease; from the natural tendency of most diseases to a favourable termination; from the influence of external causes on the favourable result of cases, different from that to which the result may be ascribed. Consequent reasonableness and importance of endeavouring to correct the conclusions drawn from the simple observation of diseases, and their treatment, by the application of the principles of Physiology and Pathology; and by the observation of the effects of remedies on the healthy body.

We treat this subject, as nearly as possible, in the same order as the Pathology; arranging the different classes of remedies according to the functions of the living body, which they appear chiefly to affect, and are used with the intention of affecting.

In regard to each class of remedies we state, first, The effects observed from them on the healthy body, and the mode of their action, when that is referable to any more general principle; next, The general indications which

thence arise for their application in disease ; then the general danger, or inconvenience to be expected from them, and the cautions thence resulting ; and lastly, we illustrate these points, by the experience of the use of the remedies in some individual diseases.

I. The *first* class of Remedies to be considered consists of those which are intended to influence the state of the Circulation.

These are our most powerful remedies. Many of them produce a decided effect on the action of the heart,—all of them affect the distribution of the blood in different branches of the arteries ; and, by the alteration they effect there, influence the vital actions in the small capillaries, which are the more frequent seat of disease.

We consider, first, Those which have a direct *Sedative* or depressing influence on the actions of the Heart and Arteries ; next, Those which increase the Excretions from, and the afflux of Blood to, certain parts of the system ; and by this *derivant* effect, lessen the quantity, and alter the distribution of the blood ; next, Those which check excessive Excretions, thereby also altering the distribution of the blood ; lastly, Those which excite or *increase* the action of the organs of Circulation.

OF THE ANTIPHLOGISTIC REGIMEN.

This term includes all such articles of regimen as have the effect of lessening the habitual stimulus, and occasional irritations, which act on the Vascular System, either directly, or through the intervention of the Nervous System.

1. The regulations in regard to Diet, Temperature, Rest, Quietude, &c. which are most effectual in this way, and constitute the strict Antiphlogistic Regimen, proper in the excited state of the Vascular System, in the height of inflammatory and febrile diseases.

2. The inconveniencies which may result from this strict regimen, and consequent modification of it proper in different cases; on account of the period of inflammation or fever; on account of the kind of inflammation, (particularly the scrofulous); on account of the type of fever: on account of the previous habits of patients.

3. The modification of the Antiphlogistic Regimen which is most effectual in obviating general plethora and local congestions of blood; its application to various chronic or habitual diseases; and the cautions requisite in regard to it, in certain circumstances of these diseases.

OF BLOODLETTING.

1. The general Sedative effect of loss of Blood on the Circulation, modified by the rapidity of its flow,—its explanation.

Consequent effects of Bloodletting on local diseased actions, and importance of these effects.

Farther effects of loss of Blood; on the Secretions, when morbidly deficient from febrile action; and on different Sensations. Consequent usefulness of this remedy as a preliminary to various others.

2. General dangers from Excessive Bloodletting; the immediate danger of sudden Exhaustion; often obscured by the reaction of the System, which takes place, in many persons, after the loss of Blood; the more remote danger—of dropsy?—of nervous disorders;—of debility, and con-

sequently increased liability to disease, from cold, or other exciting causes:—of injurious effect on the subsequent progress of the exciting disease, even when it is successful in relieving the symptoms most urgent, at the time when it is employed;—of injurious effects on one part of the symptoms, in complex cases, even when it is effectual in relieving other parts.

3. Circumstances of patients, in which either the good effects of Bloodletting, or its inconveniences, are chiefly to be expected. General influence of Age, Sex, Habit of Body, Habits of Life, Climate, Season, Period of the existing disease,—on the effects to be expected from this remedy.

4. Quantity of Blood generally to be taken in diseases for which this is the main remedy. General view of the circumstances chiefly demanding repetition of the remedy, especially of the indications from the Pulse, and from the appearance of the Blood.

5. Application of these principles to several individual diseases—Acute and Chronic.

OF THE USES OF COLD AS A SEDATIVE.

The natural effect of cold is decidedly sedative on living actions, and especially on the circulation; but several circumstances cause it to act indirectly as a stimulant or tonic, especially when applied suddenly, and quickly succeeded by heat.—Circumstances in which its sedative effect is chiefly observed, both when it is applied locally, and when generally, and indications for its use thence resulting.

General danger to be apprehended from its incautious application. Excessive depression—local determinations

of blood—local inflammation; circumstances in which these are most to be dreaded.

Practical results of the application of Cold as a sedative in inflammatory and febrile diseases.

OF THE ACTION OF SEDATIVE MEDICINES.

We give this name to those medicines only which depress the action of the vascular system, with little sensible evacuation, and no corresponding effect on the nervous system; reserving the term Narcotic for those which depress the action of the nervous system, with little effect on the vascular.

A truly sedative effect is seen from certain poisons, but few medicines are useful in this way. Use of tartar-emetic, of digitalis, of colchicum, of tobacco, of hydrocyanic acid?—Effect on the circulation from these, and indications thence arising—Dangers from excessive use of all these—Circumstances of inflammatory and febrile diseases, in which they have appeared most useful.

Statements of Italian physicians in regard to the effects observed from various medicines, called by them contra-stimulants in such diseases—Brief objections to the theory that has been connected with these observations.

Cases in which a morbid excitement of the vascular system is connected with debility, and is best obviated by tonics.

OF THE ANTIPHLOGISTIC EFFECT OF EMETICS.

Substances used with this intention;—their mode of operation—question if they are necessarily absorbed into

the blood;—their evacuating power is small, but they may act beneficially on the state of the circulation, by the sedative influence of the nausea accompanying their action, and by the alteration they effect on the distribution of the blood, and on various secretions.

Inconvenience or danger to be apprehended,—in different cases,—from the exertion attending the act of vomiting,—from the congestion of blood thereby caused in the head,—from the ultimate effect of repeated vomiting on the stomach.

Application of these principles in the case of several diseases—chiefly inflammations affecting the chest, and fevers.

OF THE ANTIPHLOGISTIC EFFECT OF CATHARTICS.

Enumeration of the substances generally used, as mild or cooling laxatives, as stomachic aperients, as drastic cathartics. Advantages from combinations of these.

Questions as to their absorption into the blood, and their mode of operation. § Their general effects on the state of the circulation—by the evacuation of part of the fluids of the body,—by a direct sedative influence on the heart,—by increase of certain secretions and alteration of the distribution of the blood,—by removing irritations which excite the vascular system.

Indications thence arising, and general means of judging of the propriety of their use.

General danger from excessive use of cathartics—on the functions of the *primæ viæ*—on the whole system; increased liability to inflammation in the parts, of which the secretions are thus excited.

Application of these medicines in various cases, where

their beneficial effect appears to be chiefly on the state of the circulation ;—in inflammatory and febrile diseases ;—in chronic diseases, attended with general or local plethora ;—in those attended with chronic external inflammation.

OF THE ANTIPHLOGISTIC EFFECT OF DIAPHORETICS.

Medicines, and combinations of medicines, used with this intention, and means of promoting their effect. Their mode of operation ; the circumstances of disease in which they are most effectual ;—nor until the force of increased vascular action has been moderated, either by previous remedies, or by the course of the disease.

General effects from these remedies—on the quantity of the fluids—on their distribution—on the temperature of the body—consequent indications.

Danger of excessive stimulation, and of bad febrile symptoms, from the early or incautious use of these remedies. Danger of debility, and especially of increased liability to inflammatory disease, from their excessive or long continued use.

Results of experience in regard to the acute diseases, in which evacuation by sweating appears most important.

Question, as to the peculiar virtues ascribed to Calomel and Opium in inflammatory and febrile complaints ? Habitual use of milder diaphoretics in various chronic diseases.

OF THE ACTION OF ERRHINES, SIALAGOGUES, AND
EXPECTORANTS.

The action of various substances on the secretions of the nose and mouth is peculiar, but availed of only in a few cases, where the alteration of the distribution of blood thus effected may be useful.

Question, How far the specific effect of Mercury on the mouth is desirable in any case?

Different medicines and expedients, by which Expectoration appears to be somewhat promoted. Important effects on the circulation thence to be expected in various diseases, and clear indication for their use. Their frequent inadequacy, and its causes. Circumstances of acute and chronic diseases to which they are best adapted; and different means of promoting their effect in different cases.

OF THE ACTION OF COUNTER-IRRITANTS.

Different means employed to excite inflammation of the skin, in the view of causing derivation of blood from diseased parts.

Facts in history of diseases which illustrate their effect. General caution in regard to their use, on account of the pain and irritation they excite, and the limited effect to be expected from them. Circumstances and period of acute diseases, and cases of chronic diseases, in which experience shews them to be most important.

OF THE ACTION OF DIURETICS.

Substances which appear to exert a specific effect on the Kidneys—their combinations—their frequent inefficacy—Circumstances which appear to frustrate or promote their action.

Inconvenience or danger which may result from the excessive use of Diuretics—chiefly on account of the other effects of these medicines on the System.

Their derivant effect on the Circulation may sometimes be useful, but their chief beneficial effect is by indirectly increasing absorption, which will be mentioned afterwards.

OF THE ACTION OF EMMENAGOGUES.

Cases in which the retention of the Menses is not a proper object of practice. Cases in which it is best remedied, by means already considered, or by others acting primarily on other departments of the System.

Question, as to the Specific Action of any medicines on this secretion. Enumeration of those which seem most effectual. Their Combinations, and the circumstances favouring their action. Caution on account of their stimulating effects in many complex cases. Beneficial effects on various functions, which result from the successful employment of means for this purpose, in cases adapted to them.

OF THE ACTION OF ASTRINGENTS.

Enumeration of these, vegetable and mineral ; their application, local and general. Their mode of action partly chemical, but the effect of internal astringents cannot be explained in that way. The degree of their effect, and general indication for their use.

Hæmorrhages and increased Excretions are connected in different cases with very different states of the Circulation in the larger vessels, and therefore different means are effectual in checking them ; but when the circulation at large is not stronger than natural, they may often be beneficially checked by these remedies.

General caution in regard to the use of Astringents, lest the discharge to which they are applied be either critical, or a preservative from worse diseases. Cases in which they are found to be most useful.

OF THE ACTION OF STIMULANTS ON THE CIRCULATION.

Increase and diminution of the action of the Vascular System, and of the action of the Nervous System, are by no means generally simultaneous ; and the indications for producing these effects are perfectly distinct : it is therefore right to consider separately the action of stimulants on these different parts of the animal economy.

Enumeration of the different means by which the Vascular System may be stimulated, either directly, or through the intervention of the Nervous.

Question, as to the Absorption of stimulating substances into the blood,—or their power of affecting the Heart's action sympathetically.

Excessive generalization attempted by different authors, of the effects of this, and other classes of remedies, especially of Sedatives and Narcotics. Almost all Stimulants act efficiently as such, only when applied within certain limits; and if applied in excess, produce an ultimate sedative effect, generally first on the Nervous, and then on the Vascular System; but this last effect is various in different cases, bears no fixed proportion to the previous stimulating effect, and cannot be reasonably ascribed to the circumstance of previous stimulation as its cause.

General indications for the use of Stimulants. Vagueness of the term "Disease of Debility." The indication for stimulants exists, in general, whenever there is danger of death occurring in the way of simple Asthenia, without any considerable disorder of the Functions of the Brain or Lungs. This happens at different periods, in many different diseases, and when it exists, is of paramount importance; but there is hardly any disease in which it occurs necessarily and uniformly, as the sole cause of danger.

General cautions, in regard to the use of stimulants, on account of the complication of the causes of danger in many diseases, and the possible aggravation of one by remedies which may avert another; and on account of the ultimate exhausting effects of most stimulating remedies when used in excess.

Practical application of Stimulants to various cases, where there is threatening of sudden death,—to inflammatory and febrile diseases,—to chronic or non-febrile diseases.

OF THE ACTION OF TONICS ON THE CIRCULATION.

We here state, first, what has been ascertained of the articles of *Regimen*, which are most truly strengthening to

the Circulation, and the other functions dependent on it. Regulation of Diet, Air, Temperature, Cold or Tepid Baths, Frictions, Exercise, Mental Occupation and Excitation, with this view. Reference to the experience of men trained for athletic exercises. Reference to Statistical Tables, proving the salubrity of rural occupations, as compared with the mode of life of the inhabitants of great towns.

Mode of action of these articles of Regimen;—by increasing the stimulating power of the blood, by habitually exciting, and therefore strengthening, all muscular organs, —by equalizing the distribution of the blood, and invigorating the circulation on the surfaces of the body, and thereby promoting digestion. Cautions necessary in the use of these several articles of Regimen, on account of their exhausting effects when used in excess; and on account of the complex nature of many diseases in which debility prevails.

Medicines, vegetable and mineral, which are thought to possess a similar tonic virtue; inconveniences from the use of some of these, and circumstances often frustrating their effect. Question, Whether any of these possess a truly tonic power over the Vascular System, independently of their effect on the Function of Digestion, and therefore on the contents of the vessels?

Use of the Tonic Regimen and Remedies, in preventing Acute Diseases, resulting from Cold, from Contagion, or Malaria; and in counteracting the tendency to Scrofula and other chronic habitual diseases. Statistical statements illustrating these points.

Tonic Plan of Treatment in the advanced stage of certain acute diseases; in the convalescence from them; in various chronic diseases; and in cases where these diseases may be apprehended.

II. The *next* class of remedies to be considered, consists of those which are used with the intention of *directly* influencing the functions of exhalation, secretion, and nutrition, to which the circulation is subservient. An ultimate effect on these actions is very often the object of remedies already considered; but they effect it by means of changes in the movement of the blood in the larger vessels. The action of other remedies on these functions seems to be independent of any alteration in the motion or distribution of the blood in the larger vessels, and referable only to some modification of the powers by which the vital actions in the small capillaries and absorbents are effected. But the efficacy of these remedies is generally inconsiderable.

OF THE ACTION OF SORBEFACIENTS.

We here consider, first, the observed indirect effect produced on the absorption of fluids exterior to the circulation, by different evacuations already considered, blood-letting, emetics, cathartics, diuretics, diaphoretics, and counter irritants; the circumstances of disease (particularly of dropsical affections), in which their beneficial action is to be expected; the circumstances by which that is most frequently frustrated; the cautions necessary in their use; the cases to which they appear severally best adapted; and the combinations with each other, or with other remedies acting on the general health, in which they are most successfully employed.

We then mention the other remedies, local and general, which appear to promote the absorption of effused fluids, independently of any obvious evacuating effect; and the application of these in the different dropsical affections.

OF THE ACTION OF DEOBSTRUENTS AND ALTERATIVES.

When solid matter is deposited, in morbid quantity, in any part of the body, it is much less under the control of any general evacuating remedies than fluids are; but still liable to much change from absorption; and various remedies appear manifestly to increase that absorption, either absolutely or relatively to the deposition. The same remedies appear, in different cases, to produce an alteration on secretions, natural or morbid, in different parts of the system, without increasing their quantity.

Enumeration of the remedies, local and general, from which these effects have been observed. Mercury, the most powerful of the general remedies of this class. Speculations in regard to their mode of action, especially of those which act locally, and which have generally a manifest stimulating effect.

Cases in which morbid deposits may be expected to be under the influence of these remedies, very limited. Effect, in this way, which can reasonably be ascribed to them. Sources of fallacy connected with observations made on their use. Dangers which result from their other effects on the system, if they are used incautiously or in excess.

Application of these remedies in individual cases; in inflammations tending to effusion of lymph, in different textures; in cases of morbid secretions without breach of texture; in certain descriptions of tumours; in certain ulcerations, especially venereal; in chronic cutaneous diseases. General views of the circumstances by which their action may be impeded or promoted in different cases.

General statement of the cases in which the Excision or Destruction of the diseased part is the chief resource.

III. The *next* head of Remedies consists of those which are destined to influence only the function of Digestion, or the condition of the *Primæ Viæ*.

Here we state, first, the dependence of the condition of these parts on Diet and Regimen ; then the effect on them produced by the different classes of remedies already considered ; by the different evacuations ; by alteratives ; by astringents ; and by stimulants and tonics ; the mode of action of each, and the general circumstances of disease to which each class is adapted.

We then consider generally the influence of such remedies as correct disorders of these parts, on the diseases of other parts of the system ; and the cautions and limitations with which this kind of practice should be pursued.

Lastly, we consider the means we possess of expelling or counteracting the noxious effects of foreign bodies lodged in the Alimentary Canal.

OF THE ACTION OF ANTHELMINTICS.

Enumeration of Substances, vegetable and mineral, used with this view ; their different modes of action, and the way of administering them. Difficulty of judging, from the symptoms they excite, of the presence of Worms in the Intestines. Cautions in regard to the use of active medicines for expelling them ; and importance of remembering that more serious complaints often coexist with, or supervene on, their presence. Beneficial effects, on various functions, nevertheless often observed to follow their expulsion.

OF THE CORRIGENTS OF THE DIFFERENT POISONS.

When Poisons have been taken into the circulation, and produced their specific effects, these may often be in some

degree counteracted, by remedies adapted to the nature of these effects; but we state here only the expedients used with the intention either of evacuating the poisons from the *Primæ Viæ*, or of correcting their noxious qualities, before they leave the stomach.

1. Emetics best suited for this purpose; means of aiding their effects; mechanical contrivances for securing the evacuation of the stomach. Cases in which they are most important.

2. Means of correcting the noxious qualities of poisons, —by the use of diluents and demulcents only;—by the use of substances which form chemical compounds with the poisons, which are wholly or nearly innoxious. Different substances which have this effect in the case of the different mineral poisons. Question as to the advantage from any such means in the case of the vegetable poisons.

IV. The *next* Class of Remedies consists of those which appear to act chiefly on the Constitution of the Fluids of the Body.

The great and manifest alterations of the composition and properties of the fluids, which take place in disease, are evidently much under the control of the vital powers; are often corrected, spontaneously, or by help of remedies, without the application of any cause that can be supposed to affect them by a merely chemical action; and are apparently very seldom influenced by causes which act on chemical principles only. The following instances only, of the action of remedies apparently on these principles, demand consideration.

I. The effect on the Symptoms of Scorbutus, produced by nutritious Food, by Vegetable Aliment, and especially by Vegetable Acids.

Question, How far Scorbutus depends on deficient nourishment only, and how far on the use of salted provisions; degree of influence of other causes besides diet in producing it; and of other remedies besides those acting chemically, in counteracting it.

II. The effect on the Symptoms of Diabetes produced by Animal Diet.

Question, How far the essential characteristics of the disease are influenced in this way—Sources of fallacy in the observations on the subject.

Question, Whether the degree of effect observed is to be explained by a chemical action, or by an alteration of vital actions.

III. The effect on the Symptoms of Gravel, produced by remedies fitted to act on the chemical constitution by the urine.

Different alkaline and acid remedies used in these complaints. Cases adapted to the use of each. Degree of advantage to be derived from them. Question, Whether their beneficial effect is strictly on the composition of the urine, or rather on the function of digestion, and composition of the blood.

IV. Supposed chemical action of preparations of Lime in Rickets. Doubts as to the reality of this effect.

V. The *last* head of Remedies to be considered, con-

sists of those which are designed to act chiefly on the functions of the Nervous System.

The morbid conditions of the Nervous System, especially when occurring in febrile and inflammatory diseases, are often more effectually controlled by remedies already considered, which act on it through the vascular system, or which improve the condition of the *primæ viæ*, than by such as have any specific action on the Nervous System. We treat here only of those which produce such effects on Sensation, Thought, or Voluntary Motion, as cannot be explained by their influence or other functions.

Two facts are remarkable, in regard to the action of these remedies: 1. That the impressions they produce, like those produced by the causes of Sensation, are liable to continual diminution from repetition; 2. That the effect of these impressions, like that of all other causes acting on the Nervous System, depends very much on the degree of intensity with which any previous cause may have acted on it; being always less, as the action of that previous cause has been greater. From these circumstances it happens, that the dose of medicines acting on the Nervous System, necessary to procure their good effect, is liable to much greater variation than that of any others.

OF THE ACTION OF NARCOTICS.

Circumstances which dispose the body to sleep, independently of medicines—Enumeration of Vegetable Substances which have this effect, and of those used with this intention. Description of their effects, and the varieties of these. Their narcotic effect not dependent on their action on the circulating system, although they produce effects here also.

Question, Whether they are necessarily absorbed into the blood in order to affect the brain and nerves? Circumstances which promote or counteract their effect—General indications for their use, and general cautions, drawn from observation of the circumstances which oppose their action, and from knowledge of their effects on the circulation in acute cases, and on the digestion in chronic Observations on the use of Narcotics, especially of Opium, in some of the more important diseases—inflammatory, febrile, functional, and organic.

OF THE ACTION OF ANTISPASMODICS.

The narcotics are the most powerful remedies of this kind; but others, which have no narcotic effect, have a certain amount of influence on spasms of the voluntary muscles when actually present. Enumeration of these. Their effect generally referable to the principle of one strong impression on the Nervous System always superseding another. Influence of pungent sensations and strong mental impressions in this way. Cases of Spasmodic diseases in which these remedies are the most useful,—generally the slighter spasms only. Caution as to their use in spasms connected with strong vascular action, or organic disease.

OF THE ACTION OF TONICS AND STIMULANTS ON THE NERVOUS SYSTEM.

The term Tonic, in relation to the Nervous System, is applied to the remedies which, when used habitually for some time, appear to render it less liable to take on a state of diseased action, whether spasm or nervous pain, or such disorder as seems to precede the development of inflammation or fever. The general Tonic Regimen has an in-

fluence in this way; but several medicines shew, in different instances, effects of this kind, which may be called Specific.

Enumeration of the circumstances of febrile, spasmodic, and painful diseases, in which most reliance is to be placed on them.

Medicines and other expedients, from which a simply stimulating effect on the actions of nerves has been observed. Cautions necessary in regard to the use of these in nervous complaints, chiefly on account of their simultaneous action on the vascular system.

OF THE ACTION OF MENTAL CAUSES ON THE NERVOUS SYSTEM.

The influence of mental causes, acting through the Nervous System, on the different *bodily* functions, having been already noticed, we have here only to consider the *regimen mentis* in the diseases of the mind itself.

The state of violent or perfect delirium admits of none but generally tranquillizing measures or restraint; but when Insanity is partial only, and many trains of thought take place nearly in the natural way, advantage may often be taken of the principle of one strong impression upon, or action in, the Nervous System, superseding or suspending another,—to withdraw the mind indirectly from those trains of thought in which morbid phenomena are exhibited.

Importance of various applications of this principle, established by much experience, in the management of cases of Hypochondriasis, Mania, and Melancholia.

FINIS.

